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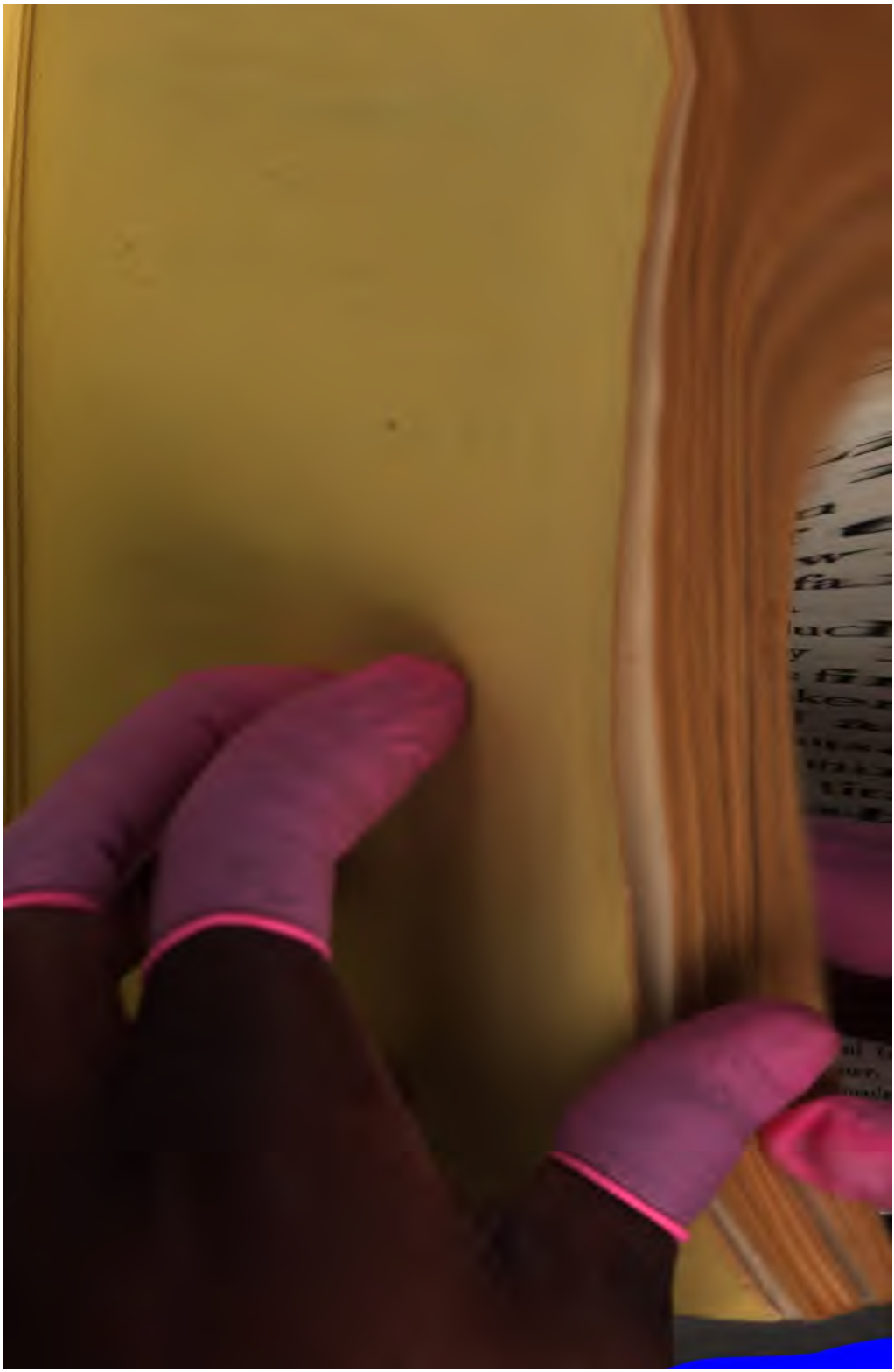

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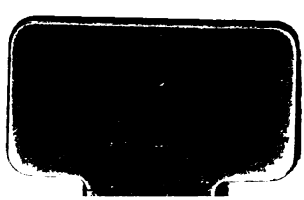

MINUTES OF PROCEEDINGS

OF THE

INSTITUTION

OF

CIVIL ENGINEERS;

WITH

ABSTRACTS OF THE DISCUSSIONS.

VOL. VIII.

SESSION 1849.

EDITED BY

CHARLES MANBY, M. INST. C.E.,

SECRETARY.

INDEX, PAGE 333.

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INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1849.

ANNUAL REPORT.

The Annual Report has, for so many years, been an address of congratulation to the Members, that the Council find it difficult on this occasion to deviate from the ordinary course, and to allow the possibility of even a temporary cessation of the hitherto unabated career of prosperity. The Institution is, however, so intimately connected with, and dependent upon, the position of the general body of the Profession, that it must necessarily suffer from the same causes which affect the prosperity of the members of that community.

In a country like Great Britain, whose distinguishing features are energy and indomitable courage, in circumstances of difficulty, it is not, however, probable, that any foreign political excitement can long continue to exercise a prejudicial effect; already the horizon is brightening, and a little reflection will demonstrate, that in proportion to the injury caused by the late stagnation, will be the activity on the resumption of the works; and it appears to be allowed, that the forced economy which has been practised during the past year, has caused such a necessity for supplies of working stock, and improvement of works, that the profession must be generally benefited, on the return of confidence in financial matters.

Viewing these circumstances carefully, the Council have endeavoured to meet the position in which they might have been placed; they have, therefore, enforced the most rigid economy in the administration of the funds, and on the recommendation of the Publication Committee, have proceeded more slowly than was generally desirable, with the publication of the Minutes of Proceedings for the Sessions of 1847 and 1848, in order not to unduly increase

the amount owing to the printer and the lithographer. Portions of the Minutes of each Session are printed, the whole of the papers and discussions are prepared for publication, and the reduced drawings are made, so that these volumes may be proceeded with, as fast as may be consistent with proper economy. Instructions have been also given to the Secretary, in the revision of the papers and the abstracts of the discussions, to reduce their length as much as the clear exposition of the views propounded will permit, and in this the co-operation of the authors and speakers is earnestly requested.

Meanwhile, in accordance with general request, the Minutes of Proceedings for the Session of 1837, (at which period these records were first published,) have been revised and reprinted, with Indexes for the Sessions of 1837, 1838, 1839, 1840, and 1841, forming the first volume of the Minutes. These, with the Indexes for 1845 and 1846, are ready for circulation, and will complete the series from the first to the fifth volumes, inclusive, and those Members who possess imperfect sets, may have them completed on application to the Secretary.

The attendance both of Members and Visitors at the ordinary meetings of the past Session, was larger than heretofore, and the discussions were sustained with more than ordinary spirit and interest.

The annual Conversazione of the President, which was held, for the first time, at the House of the Institution, was very generally approved by the Members and Visitors, and tested satisfactorily the capabilities and completeness of the newly-arranged apartments. The same system will be continued for the future, and the Conversazione of this year is announced to be held on Tuesday the 22nd of May, when the President and Council request the co-operation of all the Members and of their friends, in providing at least as interesting a collection of models and works of art as on former occasions.

Having mentioned the newly-arranged apartments, it is necessary to explain the steps that have been taken, for paying off the balance of the accounts, owing to the contractors for the alterations. After collecting, very diligently, a large portion of the original subscription, still, however, leaving a balance of £816 due from fifty-four Members and one hundred Associates, it was necessary to raise the sum of £2500, which still remained to be paid. The Honorary Solicitor of the Institution advised the Council, that, in accordance with the provisions of the Charter and Bye-laws, it was competent for them to issue Debenture Bonds for the required sum.

This course has been followed, and the amount has been subscribed* for, by the following Members and Associates, in sums varying between £200 and £25:—Messrs. J. Field, Pres., W. Cubitt, V.P., J. M. Rendel, V.P., J. Simpson, V.P., R. Stephenson, M.P., V.P., J. F. Bateman, G. P. Bidder, I. K. Brunel, J. Cubitt, J. Locke, M.P., C. May, J. R. McClean, J. Miller, W. C. Mylne, T. Sopwith, J. Clutton, T. H. Wyatt, J. E. Errington, J. Maudslay, S. M. Peto, M.P., C. Vignoles, J. C. Birkenshaw, B. Botfield, M.P., R. B. Dockray, J. S. Enys, J. Fowler, W. Froude, Sir J. J. Guest, M.P., J. Hawkshaw, B. Hick, A. S. Jee, J. G. Marshall, M.P., J. M. Parsons, S. Robinson, E. Woods, N. Beardmore, M. A. Borthwick, F. Forster, and C. Fox.

These Debenture Bonds must be paid off, and the interest upon them be provided for, by fees to the building fund, to be paid by Members on election, and from the balance of the original subscription still due (as previously stated) from many Members and Associates, who it is expected will not allow the burden to be borne by their fellow-members. It is also proposed to permit such of the subscribers to this loan, as may feel so inclined, to commute their annual subscriptions by payment of the life composition, in Debenture Bonds; by this means the debt will be speedily cancelled, and if every Member who thus commutes his subscription, will make a point of proposing at least one good Member to supply his place, the annual income of the Institution will not suffer.†

It is due to Mr. Grissell, the contractor, to state, that in the arrangement of the accounts, he has shown a desire to meet the convenience of the Institution, and has made a liberal deduction from the amount due, on the understanding that the whole matter shall be finally settled before the end of January, 1849.

It is hoped, that these arrangements will meet the approbation of the Members generally, for the Council, after most anxious consideration, saw no other method of terminating the accounts of an expenditure, which certainly exceeded their original intentions, but which was occasioned by the unforeseen bad state of the buildings,

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* When these subscriptions were collected, after the annual general meeting, Messrs. J. Field, President, W. Cubitt, V.P., and Joseph Miller, liberally presented to the Institution the sums of £100 each, instead of taking Debenture Bonds, and at the same time declared their intention of continuing to pay their annual subscription as before.

† The majority of those Members who have taken Debenture Bonds, have already declared their intention of cancelling them, by commuting their annual subscription for a Life composition.

It is, however, a subject of congratulation, that the extensive construction proposed by some of the leading speakers at the first meeting, was not attempted, as the liquidation of such claims upon the Institution would have been very onerous.

The general statement of the receipts and expenditure shows, that every economy has been practised, consistent with the position of the Institution, and that the same system must be rigidly persevered in, until, by the accession of Members, the annual income exceeds the expenditure.

The collection of the arrears and of the current subscriptions has been closely attended to, but for many reasons, the balance still due is greater than usual; it should, however, be stated that the deficiency of actual employment has, in many cases, induced the Council to exercise the utmost leniency towards those who had formerly been prompt in their annual payments.

The amount of arrears of subscriptions for 1848, due December 31st, is—

For Members of all classes residing abroad	£85	1	0			
For Members of all classes residing in England	201	12	0			
				£286	13	0

The total amount of arrears of the previous years, exclusive of 1848, is—

For Members of all classes residing abroad	£225	4	6			
For Members of all classes residing in England	165	3	6			
				£390	8	0
Total				£677	1	0

The original communications of the last session, although not very numerous, possessed great intrinsic merit, as well from the nature of the subjects, as the method of treating them, and this is most clearly shown by the animated discussions they induced.

The following may be particularly mentioned:—"On the production of Artificial Stone," by F. Ransome; "On the Drainage and Sewerage of Bristol," by James Green; "On Submarine Foundations, &c.," by A. Mitchell; "On Dock Entrances," by J. B. Redman; "On the Effects of a Storm on Sea Walls," by W. J. M. Rankine; "On the Engineering of the Rhine and the Moselle," by

G. B. W. Jackson; "On the Completion of the Works at the Bann Reservoirs," by J. F. Bateman; "On the Resistances to Railway Trains at different velocities," by D. Gooch; "On the Causes of the alteration of the line of Coast, and the formation of Shoals and of Deeps in the bed of the Sea," by J. T. Harrison; and "On Harbours of Refuge," by the Right Honourable the Earl of Lovelace.

Medals and premiums have been awarded for several of these papers; and where all were so interesting, it was difficult to discriminate between their claims.

Mr. Bateman's paper was not considered, because it was only the completion of the more extended description of the works at the Bann reservoirs, for which he had previously received a Telford Medal. The original paper, as intended to have been published in the Transactions, will now be printed in the Minutes of Proceedings for 1848, together with the second part, as read during the last Session.

Mr. Gooch's paper was also put aside, because it had been published by the Government,* and was merely brought before the Institution, under a peculiar arrangement, in order to raise a discussion upon so interesting a subject.

The consideration of Mr. Froude's paper, "On the law which governs the discharge of Elastic Fluids, under pressure, through short tubes and orifices," which was delayed last Session, to afford time for further experiments, must be again postponed, because the author has not been able to devote himself to the prosecution of the subject.

The following medals and premiums have been awarded:—

A Telford Medal, in silver, and a Council Premium in Books, suitably bound and inscribed, to John Thornhill Harrison, M. Inst. C. E., for his "Observations on the Causes that are in constant operation, tending to alter the Outline of Coasts, to affect the Entrances of Rivers and Harbours, and to form Shoals and Deeps in the bed of the Sea."

A Telford Medal, in silver, to the Right Honourable the Earl of Lovelace, &c. &c., for his paper "On Harbours of Refuge."

A Telford Medal, in silver, to Alexander Mitchell, M. Inst. C.E., for his paper "On Submarine Foundations, particularly the Screw Pile and Mooring."

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* *Vide* Minutes of Evidence taken before the Gauge Commissioners, p. 135. London, 1846.

A Telford Medal, in silver, to Frederick Ransome, Assoc. Inst. C. E., for his paper "On the production of Artificial Stone, by the combination of Silica, in a liquid form, with Sand and other materials."

A Council Premium of Books, suitably bound and inscribed, to George Briant Wheeler Jackson, Assoc. Inst. C. E., for his paper on "The Engineering of the Rhine, including a Translation of M. Van den Burgh's paper on the Improvements in the Moselle."

A Telford Premium of Books, suitably bound and inscribed, to John Baldry Redman, M. Inst. C. E., for his paper "On the Forms and Positions of Dock Entrances in a Tideway; illustrated by the principal examples in the Port of London."

A Telford Premium of Books, suitably bound and inscribed, to James Green, M. Inst. C. E., for his "Account of the recent Improvements in the Drainage and Sewerage of Bristol."

A Telford Premium of Books, suitably bound and inscribed, to William John Macquorn Rankine, Assoc. Inst. C. E., for his "Account of the Effects of the Storm of the 6th December, 1847, on four Sea Walls, or Bulwarks, of different forms, as illustrating the principle of the construction of Sea Defences."

It will be observed that the Council Premiums have been awarded to Mr. Harrison and to Mr. Jackson.

To Mr. Harrison, in addition to a Telford Medal, for his paper on a subject of vast interest to Engineers, and in the treatment of which he displayed great accuracy of observation, and powers of drawing useful deductions.

To Mr. Jackson for his equally useful paper, chiefly descriptive of executed works of magnitude, which, although not possessing much novelty, deserve record in the archives of the Institution. The description exhibits considerable industry and observation on the part of the author. He received very valuable assistance in his researches from M. Van den Burgh, the Engineer-in-chief of the works on the Meuse, to whom the thanks of the Institution are justly due, for this mark of his solicitude for its interests, and for his personal attention to one of its Members.

The paper of the Earl of Lovelace is an analysis of the Government Reports on the important question of the formation of Harbours of Refuge. It reviews with great ability, and with a freedom from preconceived opinions, which could perhaps scarcely have been found in a professional man, the various sites and modes of construction that have been proposed for breakwaters, and other works

of a similar nature. In the discussion, after paying deserved compliments to Lord Lovelace, for the able and impartial manner in which he had treated so interesting a subject, the speakers explained the actual circumstances and conditions of the works which had been instanced as failures, and relative to which there appeared to exist some misapprehension; the comparative merits of the long slope and the vertical wall were also again argued, and some very valuable opinions were elicited. The Council have extreme pleasure in offering to the Earl of Lovelace, the Medal established by their first President, Telford, as a mark of the sense entertained by the Institution of the ability of the author, and the love for scientific research which induced him, amidst his senatorial avocations, to devote the necessary time for drawing up this paper, which they trust will be but the precursor of others.

Mr. Mitchell's paper "On Submarine Foundations" is more correctly a description of the works executed with the screw pile and mooring of his invention. These works are of a varied nature, and are now extremely interesting, because they have the test of time in their favour; and the approbation generally bestowed upon the system, by the Engineers of eminence who took part in the discussion, show that the Council are not in error in awarding a Telford Medal to the ingenious projector, whose talent and perseverance, under physical difficulties of no ordinary character, deserve the highest encomium.

Mr. F. Ransome's paper "On the formation of Artificial Stone," induced an animated and interesting discussion which extended over several evenings. The Council hope, that as so many of their Members and Associates have under their control, manufactories where interesting processes are carried on, they will send descriptions of them, with specimens of the production, to the meetings; the publicity so afforded, and the opinions elicited, must be equally useful to them and to the Institution.

The paper by Mr. Redman, "On the forms of Dock Entrances," and that by Mr. Rankine, "On the effects of a Storm upon some Sea-walls," are both records of observations of the effects upon engineering works, under particular circumstances, or in peculiar localities, and are valuable, as forming a portion of a book of reference, which the proceedings of the Institution should become.

Mr. Green's long practice in the profession, and the large works he had been engaged in, gave value to an account of even a small work executed by him. The first step in the improvement of the drainage of a place so notoriously deficient as Bristol, must be

interesting, when public attention is so pointedly directed to the vital questions of the amelioration of the systems of drainage and sewerage of towns, and of a more copious supply of gas and water at a reduced cost. The Institution is the natural field for the discussion of these questions, and the Council hope these subjects will be brought fully before the meetings during the present Session.

Considerable additions have been made to the list of subjects for papers, in the hope that many of the Members who are not fully occupied at present, will devote themselves to the consideration of the topics suggested. It is believed that in bringing before the meetings the result of their labours, they will benefit themselves, because, after the exhibition of professional skill upon works, there is no place where an engineer can so legitimately display his natural, or acquired talents, as at the Institution, towards which the attention of the public is continually directed; and it is certain, that the origin of the actual position of several members of the profession, may be traced to an exhibition of talent, either in a paper, or a discussion at some of the meetings.

The presents of books, maps, &c., have not been so numerous as heretofore; the Council must therefore impress upon the Members of all classes, to interest themselves for the improvement of the library, which should be rendered as useful as possible, by the addition of all professional works of reference. They would also again remind those gentlemen who have lately joined the Institution, of an engagement they made previous to their election, to present some paper, or book, within a given period, and which has in many instances been neglected.

The Honourable Board of Ordnance, and the Admiralty, continue their valuable contributions of the Ordnance maps and the Admiralty charts, at the instance of your Honorary Members, Admiral Beaufort and Major-General Colby; other public Boards also contribute their reports and proceedings.

Mr. Rennie has presented a portrait of Mr. Whidbey, the coadjutor of his late Father in the works at the Plymouth Breakwater. The Council hope, that the example of the donors of the portraits, surrounding the Members at the evening meetings, will not be lost upon those who have in their possession portraits of eminent engineers, which should be placed among their compeers, within the walls of this Institution.

The Minutes of Proceedings have received liberal contributions of illustrations, from Members of the Institution, as well as from

Editors of scientific journals, with whom the best understanding is established.

The tabular statement of the transfers, elections, deceases, and resignations of Members of all classes, during the year 1847 and 1848, appears thus:—

	Honorary Members.	Members.	Associates.	Graduates.	Annual Increase.
1847. Transferred to Members	..	..	1	3	
Transferred to Associate	..	..	..	1	
Elections	..	8	21	..	29—19=10
Deceases	..	3	6	..	19
Resignations	..	2	8	..	
1848. Transferred to Members	..	..	2	1	
Transferred to Associate	..	..	..	1	
Elections	..	11	27	..	38—22=16
Deceases	..	3	4	1	22
Resignations	..	1	11	2	
Members of all classes on the Books, Dec. 31, 1848	35	224	332	35	= 626

If the Honorary Members and Graduates are omitted from the calculation, the annual increase of Members and Associates stands thus:—

Years.	Members.	Associates.	Members Elected.	Deceases, Resignations, and Erasures.	Effective Increase.
1843	7	37	44	6	38
1844	8	36	44	42	2
1845	10	34	44	7	37
1846	7	23	30	10	20
1847	8	21	29	19	10
1848	11	27	38	22	16

The following Members and Associates have, from various circumstances, tendered their resignations, which have been accepted by the Council in accordance with Clause 9, Section V., of the Bye-Laws, their several subscriptions having been paid:—Messrs. James Taddy Blackburn, James St. George Burke, John Gandell, Major Jervis, Henry Kennedy, George Lawford, William Lawford,

William Wilkinson Nicholson, Charles Ower, and George Samuel Sanderson, Associates; George Grove and Jonas Stawell, Graduates.

Although the deceases are not so numerous as last year, the Institution has to regret the loss of several valuable Members, whose memoirs, however, are not so complete as is desirable, in consequence of the difficulty of procuring the necessary information. Nevertheless the Council beg to return their thanks to the relatives and friends of the deceased Members, for their assistance in drawing up these records.

The deceases are,—Benjamin Cubitt, Samuel Fowls, and Thomas Hopkins, Members; Lieutenant-Colonel Brandreth, Pieter Laurentz Campbell, Francis Carleton, and Thomas Ennis Steele, Associates; and John Pope, Graduate.

Mr. Benjamin Cubitt was born in the county of Norfolk in the year 1795, and after serving a regular apprenticeship to his elder brother, Mr. Cubitt, V. P., as a millwright, he became foreman of the works of Mr. Penn, at Greenwich. He then took charge of the extensive Engine and Machinery Building Works of Messrs. Fenton, Murray, and Wood, of Leeds, and during the period of nearly ten years that he remained there, great improvements were introduced into the machines executed by that firm. He then assumed the same position at the extensive works of Mr. Rothwell, at Bolton, on the secession of the late Mr. Hick from the concern, and after a service of ten years, only quitted that post to take charge of the Locomotive Department of the Brighton, Croydon, and Dover Railways, of which latter railway, his brother was the Engineer-in-Chief. In this latter capacity, he had an opportunity of exhibiting the good results of his practical education, and the establishment under his charge was a model of good management. On the separation of the three Companies, he was appointed the Superintendent Engineer of the Locomotive Department of the Great Northern Railway, and was actively engaged in the organization of the working stock of the line, when he died suddenly on the 12th of January, 1848, universally regretted by his friends, for his private virtues and his excellent qualities, and by the profession and his employers, for his talents, experience, sound practical mechanical knowledge and judgment, and his unflinching integrity.

He was not an old Member of the Institution, having only been elected in 1843, but he served on the Council very zealously, until his removal to Lincoln, and on his retirement carried with him the esteem and respect of all the other Members.

Mr. SAMUEL FOWLS was born at Allostock, near Peover, Cheshire, in the year 1779, whence the family removed to Wilton Northwich, where his Father had taken a farm, upon which the subject of this memoir was put to work at nine years of age, after having received only the imperfect rudiments of education afforded by the parish clerk. Having exhibited a taste for more active employment than farming, he was apprenticed to a joiner and builder, and after his hours of daily labour, devoted himself to the acquisition of useful knowledge, and the cultivation of the sciences.

He then turned his attention to the study of mechanics, and was eventually employed in the construction and repairs of the machinery connected with the salt-works of the district.

In the year 1809, in consequence of the resignation of Mr. Johnson, and at the recommendation of Mr. Telford, by whom he was highly esteemed, he was appointed Engineer to the Trustees of the River Weaver, which post he held until his decease. Several of the double locks and weirs on that navigation, as well as the basin and piers at Weston Point, where the Weaver falls into the Mersey, were constructed, or completed under his direction.

He also held the post of Bridge Master of the County of Chester until within a few years, and under his superintendence several useful public works were designed and completed. His advice and assistance were frequently obtained by other engineers, on account of his extensive local knowledge. He was a sound practical engineer, and, in all respects, an estimable man. On his decease, the Trustees of the River Weaver wrote in these terms to his family:—

"The Trustees, while lamenting the loss of so invaluable an officer, desire to record their high sense of his integrity, zeal, and the extreme ability with which he conducted their works during such a lengthened period; and which, coupled with his uniform correctness of conduct, secured to him their respect and unlimited confidence."

He was a very old Member of this Institution, having been elected in 1820, and whenever he came to London always attended the Meetings.

Mr. THOMAS HOPKINS was a grandson of the late Mr. Evan Hopkins, who was engaged in South Wales, during the last century, in the construction of canals, tramroads, and other works. He was the second son of the late Mr. Roger Hopkins, for many years a Member of this Institution, and who was one of the early railway Engineers, having constructed the tramroad near Merthyr-Tydvil,

on which the first railway locomotive engine was tried by Trevithick, in the year 1804; he was also the engineer of numerous railways, canals, tramroads, bridges, and other public works in various parts of England and Wales.

Mr. Thomas Hopkins was brought up under his Father's instruction as an engineer, and afterwards entered into partnership with him and with his elder Brother, Mr. Rice Hopkins (M. Inst. C. E.). They jointly superintended the formation of railways and other works in the West of England and in South Wales. They also erected the Victoria Iron Works in Monmouthshire, and were, for several years, Directors of that undertaking. In the years 1845 and 1846 he was engaged with his Brother in the preparation of plans, sections, and estimates for several proposed railways; but in 1847, on his health failing, he travelled under medical advice to Rome, where he died on the 8th of February, 1848, in his 39th year.

He was elected a Member of the Institution in 1836, and contributed descriptions of several works, which had been erected under his superintendence.

Lieutenant-Colonel Henry Rowland Brandreth, R.E., F.R.S., &c., was born at Southampton, in the year 1794. Being intended by his father, Captain Brandreth, R.N., for the Ordnance Department of the Army, he went to the Academies of Marlow and Woolwich, at both of which he passed early and brilliant examinations. On receiving his commission, he served for the usual period at Chatham, and subsequently on the Survey in England, and was then sent on service to North America and to the West Indies. He then became Military Secretary to Sir Charles Maxwell, Governor of the Leeward Islands, where he is still remembered for the energy, tact, and benevolence, with which he fulfilled the duties of that office.

In 1825 he was sent to Antigua, to erect iron barracks for resisting the hurricanes; but when, on arrival, he discovered that the plans furnished him were not suited to the locality, and were not calculated for the precise service, he ventured to construct buildings from his own plans, which obtained the approbation of the authorities, and completely answered the purpose for which they were intended.

In 1829 he was employed at the Island of Ascension, to report to the Admiralty on the defence of the island, the means of accommodation for troops, the facilities for procuring water from the

mountain districts, the actual state of the cultivation, the encouragement necessary to raise stock and vegetables for the ships of war touching there, and on the general prospects of the island as a colony. His reports were so satisfactory, that they induced, in a great degree, his subsequent appointment as Civil Engineer and Architect to the Admiralty. He also embraced the opportunity of contributing to the Transactions of the Geographical Society a paper upon the formation of Ascension Island.

Between the years 1831 and 1836 he was employed as a Commissioner under the Boundary Act;—was present at the siege of Antwerp, of which he wrote an account; and by command of H. M. William IV., read the notes to him at a private audience;—revised the boundary of the borough of Hertford;—was the Commissioner for reforming the establishment of St. Helena;—was a Commissioner under the Municipal Corporation Act, for settling the boundaries of towns in England and in Ireland, and was finally engaged in an inquiry into the mode of providing prisons for convicts in Ireland, and in remodelling the mode of transportation.

In the beginning of 1837 he commenced the duties of Director of Works to the Admiralty, which post soon became very arduous and important, as new works of magnitude were demanded by the exigencies of the service; and the zeal and talent he displayed in rendering available every improvement in science, and in obtaining the best advice and assistance of eminent men in every profession, are attested by the works at all the Royal Dockyards and Naval Arsenals, and the satisfactory reports from the Commissions of which he formed part. In 1838–9, he was offered by Lord Glenelg the Government of South Australia, which however he declined. In 1846 he resigned his position under the Admiralty, when their Lordships, in according their last testimony of approbation, stated they could not use more fitting terms, than those employed by the two previous Boards of Admiralty, under which he had served, namely, "that the public never had a more useful or a more meritorious servant."

In 1847 he received his promotion as Lieutenant-Colonel, having been previously named one of the Commissioners of the Railway Board. In this position, as at the Admiralty, he was continually in communication with Civil Engineers, and the urbanity and unruffled temper with which he performed his duties induced the esteem and respect of every one. He was elected an Associate of the Institution in 1838, and was always ready to contribute in any way to its success.

In private life his benevolence and ready sympathy for distress endeared him to all his friends, who admired him for his cultivated literary taste and acquirements; his mind was filled and regulated by Christian faith and principle, and his decease, which occurred suddenly from the rupture of a blood-vessel on the brain, on the 20th of February, 1848, created a vacancy which will not soon be adequately filled.

Mr. PIETER LAURENTZ CAMPBELL was born at the Cape of Good Hope, in the year 1809. He was the son of a distinguished officer, whose services, whilst in command of the 72nd Highlanders, are recorded by the War Office in a recent publication. He was entered at the age of thirteen as a cadet at Sandhurst, whence he returned to the Cape of Good Hope, and served on the personal staff of Sir Richard Bourke, as his Private Secretary, in which position he exhibited the germ of that aptitude for official duties, for which he subsequently became so remarkable. His predilection for the service was, however, so great, that in 1830 he entered the army as an Ensign in the 55th Regiment, and accompanied it to India, but soon exchanged into the 89th, and returned to England, in consequence of the climate being uncongenial to his health. When Sir Richard Bourke became Governor of New South Wales, he suggested Mr. Campbell's exchanging into the 21st Fusileers, then embarking for the Australian colonies, and again placed him upon the staff, until an active police magistrate being required for the large and, at that time, disturbed district of Maitland, Mr. Campbell received the appointment, which he filled with such credit to himself and benefit to the country, that he was soon advanced to the post of Police Magistrate of Paramatta. He was then appointed Acting Treasurer for the colony, and retained these positions until the year 1840, when, on his health failing, he returned to England with his family, and in a short time obtained a position in the Board of Trade, where he soon established such a reputation, that on his accepting the post of Secretary to the Manchester and Leeds Railway, the Earl of Dalhousie, then President of the Board of Trade, was pleased to express himself to this effect:—"I feel very sensible regret in losing your assistance in this department; your proceedings whilst serving with us, having led me to anticipate great advantage to the office from your co-operation, and I am truly sorry to be deprived of it so soon."

The qualities exhibited by Mr. Campbell, in his new position, attracted the attention of the South-Western Railway Company, whose extensive operations demanded the services of a gentleman

of first-rate ability, to advise and assist the Board in their negociations, and in the numerous Parliamentary contests in which they were then engaged. He was accordingly appointed Secretary in 1846, and his unwearied exertions, which there can be no doubt hastened his death, materially contributed to the success of the Company, in their struggles to obtain the Bills for their western extensions.

The excellence of Mr. Campbell's private character, and his moral worth, are fully attested by the confidence he inspired in all with whom he became connected; and in his public career he was equally distinguished for his talents, his indomitable energy and devotion to the duties of his office, as for his courtesy and kindness of demeanour to all with whom he came in contact, during his brief but useful career, and he will be long and deservedly regretted.

He was elected an Associate in 1846, but up to the period of his lamented decease, his time was too much occupied with the affairs of the Company, he so ably represented, to be able to devote himself to the Institution as, with his usual energy, he would otherwise have done.

Mr. Francis Carleton, a native of the city of Dublin, began his career in the service of the Bank of Ireland, where he soon distinguished himself, as possessing superior business habits, with a peculiar aptitude for official correspondence and financial details, combined with remarkable steadiness and attention. These qualifications induced his being intrusted, at an early age, with the management of the Branch Banks department of that establishment, which he continued to conduct with satisfaction, during his connexion with it. A natural delicacy of constitution, combined with the decease of some of his family from consumption, warned Mr. Carleton, that his frame was not likely long to resist that close attention to official hours, which the important position he held so unremittingly demanded. Under these circumstances he abandoned the flattering prospects before him, and retired from duties, which his state of health rendered at once irksome and dangerous.

Mr. Carleton's peculiar habits of business then recommended him to Mr. C. Wye Williams (Assoc. Inst. C.E.), the Founder and Managing Director of the Dublin Steam Packet Company, to which enterprise he was appointed Secretary in the year 1826.

Thus introduced to the business of steam navigation, he soon became conversant with the peculiarities of that branch of what,

from its importance, may be called the public service. He was in time elected one of the Directors of the Company, on its being incorporated by Act of Parliament, was shortly after appointed Assistant Managing Director, and continued one of its Directors to the period of his lamented death.

On the Transatlantic Steam-ship Company being established, under the auspices of the Dublin Steam Packet Company, Mr. Carleton took an active part in its formation and management, while it continued to maintain an intercourse between Liverpool and New York. The experience of three years, however, having satisfied its Directors, that the expense of equipping and maintaining a transatlantic intercourse by steam vessels, without the aid of a Government contract, was incompatible with a successful pursuit of their object, and a prospect of a more profitable employment for their vessels presenting itself, in consequence of a proposal from the proprietors of the Peninsular Steam Packet Company to join that enterprise, their two vessels, the Great Liverpool and the Oriental, were transferred to the latter Company, which was then under contract for the conveyance of the mails to Lisbon, Cadiz, and Gibraltar, preparatory to the formation of the existing Peninsular and Oriental Steam-navigation Company, of which new Company Mr. Carleton became one of the three Managing Directors.

In the subsequent negotiations with Her Majesty's Government, for a royal charter, and obtaining a contract for the conveyance of the Mediterranean mails, Mr. Carleton took an active part, in conjunction with the other Managers, Mr. Willcox and Mr. Anderson, and the successful prosecution of that enterprise, is the best test of the efficiency of its management.

Mr. Carleton became an Associate of the Institution in 1845. His decease, at the early age of forty-eight years, deprives the Peninsular and Oriental Company of a most efficient Director, and causes a feeling of regret among a large circle of friends.

Mr. Thomas Ennis Steele was the descendant of an ancient and honourable family in the County Clare, where he inherited a beautiful estate, and few men have commenced their career with brighter prospects. He graduated and took his degrees at Trinity College, Dublin, about the year 1817; he then removed to Trinity College, Cambridge, in 1820, and obtained the degree of Master of Arts in that University, on the books of which his name was always retained, and he regularly appeared at the elections. He was an elegant classical scholar, but more particularly directed his atten-

tion to Mathematics, Mechanics, and the application of Chemistry to the Arts; he also, at one period, directed much of his time to the study of Geology, with the avowed object of preparing himself for travelling in the East; a project which was probably prevented by his entanglement in politics.

The bad state of the navigation of the river Shannon being very prejudicial to the interests of his favourite country, he determined to make a personal survey of the bed of the river, which he did in the most complete manner, employing sometimes very original means; such, for instance, as stepping along the line of a reef, or shoal, supporting himself with one hand upon the stern of a boat, whilst he measured and recorded all the inequalities of the surface, and ascertained the nature of the rocks, or ground. An account of this survey was published by him, and no greater proof of its utility can be given, than the fact of the greater portion of his suggestions having been followed, in the works that have been since executed.

His attention being thus directed to the diving-bell, he devised several alterations in its construction and application; particularly a method of lighting the divers, during their submarine labours. All these, with many similar subjects, were published in the current periodicals of the day, and some of them were communicated to this Institution.

At a later period a favourite theme, upon which he repeatedly addressed the Institution, was the purchase of the birth-place of Sir Isaac Newton, and its preservation by the scientific world, in the same manner that Shakspere's house has since been obtained by the exertions of literary and dramatic men.

He embarked deeply in Irish politics, and became the devoted follower of O'Connell, about the year 1825; but upon that portion of his career, the incumbrance of his fortune, and the melancholy termination of the life of a man who might have been an invaluable member of society, this memoir cannot dwell. His political opponents, however, all acknowledged his honourable feelings, and the entire absence of selfishness in his actions, and in his last hours he had the satisfaction of seeing the bitterest among them, vying with each other, in their anxiety to serve honest Tom Steele.

He was the most chivalrously-minded of men, the most affectionate of friends, and the most devoted of followers, still preserving his independence of mind. He entertained no private resentments, which might not be instantly extinguished, by the

slightest approach to conciliation, even on the part of one who might have deeply injured him; and it may with truth be said, that he never deliberately committed an act by which he thought he should lose a friend, create an enemy, or injure a fellow-creature.

After the decease of his chosen leader, Mr. Steele abandoned politics, and though visibly declining in health and spirits, he steadfastly rejected all offers of assistance from his friends, who desired to cheer the evening of his days, and on the 15th of June, 1848, he expired, a man of fallen fortune, a crushed spirit and a broken heart, but universally beloved by all who knew and could estimate the man apart from the politician.

He was elected an Associate of the Institution in 1827, and contributed several notices to its proceedings.

Mr. JOHN POPE was born in London in the year 1820; he was articled as a pupil to his uncle, Mr. Cubitt, V.P., and became a Graduate of the Institution (in 1841) at the earliest age at which he could be admitted.

He was employed as one of the Assistant Engineers on the South-Eastern Railway, having also particularly entrusted to him, the superintendence of a portion of the works at Folkestone Harbour. He subsequently received the appointment of Colonial Engineer and Clerk of the Public Works at Hong Kong, where, between the years 1844 and 1847, he designed and executed several important public improvements. His zeal, talents, and integrity of character gave promise of future eminence, but he fell a victim to the fever of the country in December, 1847, at the early age of twenty-seven years.

The majority of these gentlemen were Associates, and these short records show how valuable that class could prove to the Institution, if they would communicate to the meetings the varied experience they possess.

In accordance with the provisions of the bye-laws, Mr. Field is proposed, for the second time, as President, and as, by the present regulations, a considerable change must be made each alternate year in the constitution of the Council, only two new names are now proposed for each class of Members and Associates.

Mr. Sopwith, Member, has retired, because his avocations in Cumberland, completely monopolized his time, and prevented his being so useful a Member of the Council as he desired.

Messrs. Clutton and Wyatt also retire, after giving their services for one year; as the Associates are not re-eligible until after an interval of twelve months.

The Council, in surrendering the trust committed to them, offer their best wishes for the increased prosperity of the Profession, and trust that their successors may, at the next annual meeting, be able to congratulate the Members on the return of a season of active employment and of general prosperity, both in and out of the Institution.

RECEIPTS.

Dr.	£.	s.	d.	£.	s.	d.
To Balance in the hands of the Treasurer				31	7	0
— Subscriptions and Fees:—						
Arrears	79	5	6			
Current	1,388	11	7			
Fees	121	6	0			
				1,589	3	1
— House, Cannon-row, for Rent				33	7	10
— Telford Fund, Dividend 2 Quarters, due Christmas, 1847				28	6	9
— Council Premiums				40	0	0
— Publication:—Sale of Transactions and Minutes				41	2	3
— Dividend:—Messrs. Cockburn and Co., late Bankers of the Institution:—						
General Account	41	4	4			
Life Subscriptions	23	19	0			
				65	3	4
				£1,828	10	3

PAYMENTS.

Cr.	£.	s.	d.	£.	s.	d.
By House, Great George-street, for Alterations				4	2	4
Ditto, for Rent	417	10	10			
Rates and Taxes	59	6	0			
Insurance	18	19	9			
				495	16	7
— Salaries				225	0	0
— Commission on Collection of Subscriptions				75	14	4
— Clerk, Messenger, and Housekeeper				122	13	0
— Postage and Parcels:—						
General	33	5	11			
Parcels	0	3	5			
				33	9	4
— Stationery, Engraving, and Printing Circulars, Cards, &c.				40	14	5
— Coals, Candles, Oil, and Gas:—						
Coals	30	8	0			
Candles	10	8	4			
Oil and Lamps	0	8	0			
Gas	29	10	3			
				70	14	7
— Tea and Coffee				35	11	8
— Library:—						
Books	15	4	6			
Periodicals	34	12	9			
				49	17	3
— Publication:—Transactions and Minutes of Proceedings				427	19	7
— Furniture, Gas Fittings, Lamps, &c.				9	0	6
— Telford Premiums				17	18	4
— Council Premiums				5	8	6
— Diplomas for Members				2	7	8
— Manuscripts, Original Papers, and Drawings				10	15	3
— Incidental Expenses:—						
Gratuities and Christmas Gifts	0	9	6			
Sending Invitations and Cards, procuring Models, &c., for Conversazione	43	16	7			
Occasional Assistance	18	8	8			
Assistance at Meetings	6	6	0			
Cleaning Windows and Sweeping Chimneys	1	9	0			
Chandlery Accounts	3	1	6			
Household Utensils, Repairs and Expenses	22	19	4			
				96	10	7
				1,723	13	11
— Balance in the hands of the Treasurer				104	16	4
				£1,828	10	3

Examined and compared the above Account with the vouchers entered in the Cash Book, and find them to be correct, leaving a balance in the hands of the Treasurer of One Hundred and Four Pounds Sixteen Shillings and Four Pence.—January 1st, 1849.

(Signed) W. NEWTON, JOHN WRIGHT, } *Auditors.*

CHARLES MANBY, *Secretary.*

January 16th, 1849.

PREMIUMS AWARDED,
SESSION 1848.

THE Council of the Institution of Civil Engineers have awarded the following Premiums:—

1. A Telford Medal, in Silver, and a Council Premium in Books, suitably bound and inscribed, to John Thornhill Harrison, M. Inst. C. E., for his "Observations on the Causes that are in constant operation, tending to alter the Outline of Coasts, to affect the Entrances of Rivers and Harbours, and to form Shoals and Deeps in the bed of the Sea."
2. A Telford Medal, in Silver, to the Right Honourable the Earl of Lovelace, &c. &c., for his paper "On Harbours of Refuge."
3. A Telford Medal, in Silver, to Alexander Mitchell, M. Inst. C. E., for his paper "On Submarine Foundations, particularly the Screw Pile and Mooring."
4. A Telford Medal, in Silver, to Frederick Ransome, Assoc. Inst. C. E., for his paper "On the production of Artificial Stone, by the combination of Silica, in a liquid form, with Sand and other materials."
5. A Council Premium of Books, suitably bound and inscribed, to George Briant Wheeler Jackson, Assoc. Inst. C. E., for his paper on "The Engineering of the Rhine, including a Translation of M. Van den Burgh's Paper, on the Improvements in the Moselle."
6. A Telford Premium of Books, suitably bound and inscribed, to John Baldry Redman, M. Inst. C. E., for his paper "On the Forms and Positions of Dock Entrances, in a Tideway; illustrated by the principal examples in the Port of London."
7. A Telford Premium of Books, suitably bound and inscribed, to James Green, M. Inst. C. E., for his "Account of the recent Improvements in the Drainage and Sewerage of Bristol."
8. A Telford Premium of Books, suitably bound and inscribed, to William John Macquorn Rankine, Assoc. Inst. C. E., for his "Account of the Effects of the Storm of the 6th December, 1847, on four Sea Walls, or Bulwarks, of different forms, as illustrating the principle of the construction of Sea Defences."

SUBJECTS FOR PREMIUMS,
SESSION 1849.

THE Council invite communications on the following, as well as other subjects, for Premiums:—

1. The best modes of combining materials, by arranging, or cementing them together, so as to insure uniformity of action from change of temperature.
2. The history of the invention and of the improvements in the construction of the Skew, or Oblique Arch, and observations on the effects of Piers in the course of Rivers.

   It is important to obtain an authentic history of this invention while the subject is so recent, as it is probably the most remarkable introduction into construction, since that of groined vaults.
3. Accounts of Railway Viaducts of considerable extent, whether composed of stone, or brick arches, or of girders of timber, or metal.
4. The construction of Retaining and Wharf Walls, with examples of failure, and the causes.
5. The forms of Piers, Sea Walls, and Shore Defences, illustrated by examples of known constructions, such as the Cob Wall at Lyme Regis, &c.
6. The construction of Piers, Moles, and Breakwaters, whether solid, or on arches, or floating in a tideway.
7. The best system of forming Artificial Foundations, showing the ratio of pressure to surface, and the soil best calculated to sustain heavy structures; illustrated by the best examples in modern practice, and by accounts of the failures of large works.
8. The improvement and maintenance of Harbours, both natural and artificial.
9. The selection of sites for, and the principles of, the construction of Breakwaters and Harbours of Refuge; illustrated by examples of existing works.
10. The arrangement of Docks to accommodate a large export and import trade, connected with inland navigation and railway transit, and with extensive warehouses; showing the methods employed for preventing the accumulation of silt, or sand, at the entrance, or within the docks.
11. The arrangements of Naval Arsenals, including the Work-

shops for the Steam Machinery, calculated to meet the exigencies of the present system of the employment of a Steam Navy.

12. The modes of Irrigation and of Drainage adopted in the United Kingdom; or descriptions of works of a similar nature in Holland, Spain, Italy, and other countries.
13. The Drainage and Sewerage of Cities and large Towns; exemplified by accounts of the system at present pursued, whether by a rapid fall into rivers, or by flushing from a head of water.
14. The movement of Shingle on exposed Beaches, and the deposition of Silt in Harbours, or at the mouths of Rivers.
15. An account of the waste, or increase of the Land on any part of the Coast of Great Britain, the nature of the Soil, the direction of the Tides, Currents, Rivers, Estuaries, &c.; with the means adopted for retarding, or preventing the waste of the Land.
16. The conveyance of Fluids in Pipes, under pressure, and the circumstances which usually affect the velocity of their Currents; with accounts of Water-works and Gas-works.
17. The construction of Coffer-dams, particularly in situations where the driving of Piles is difficult, or scarcely practicable.
18. Improvements in the construction of Girder Bridges, whether of Trussed Timber, of Cast Iron, trussed, or plain, or of hollow wrought Iron beams.
19. The construction of Wrought Iron Roofs for covering considerable areas.
20. Accounts of experiments on the Strength of Trusses; directed to the determination of that form and those dimensions of the truss, by which it is equally liable to rupture in every part.
21. The comparative advantages of Iron and Wood, or of both materials combined, as employed in the construction of Steam Vessels, with drawings and descriptions.
22. The best forms for River and Sea-going Steam Vessels, with practical examples, giving the sizes of Steam Vessels of all classes, in comparison with their Engine Power, the principal dimensions of the Engines and Vessels, draught of water, tonnage, speed, consumption of fuel, and the various modes of propulsion.
23. The best forms, dimensions, and positions of the Float Boards

of Paddle Wheels, with reference to the uniform action on the water, to the speed produced, the power of the Engines, and the area of the midship section of Steam Vessels.

24. The construction of Lighthouses, whether of Stone, or Metal, in exposed positions, or on bad foundations; with the results of the present improved system of lighting.
25. The results of the use of Tubular Boilers, and of Steam at an increased pressure, for Marine Engines.
26. The best application of the principle of Expansion, to the improvement of stationary, locomotive, or marine Steam Engines, with examples of the effect of such application, from actual experiment, and a description of the Engines experimented upon.
27. The term "Horse Power," as applied to Steam Engines.
28. Accounts of experiments, having for their object to determine the friction of Machinery, and the power absorbed by various portions of the same Machinery under various circumstances.
29. The Economy of Railways as a means of transit, comprising the classification of the traffic, in relation to the most appropriate speeds for the conveyance of Passengers and Merchandize.
30. The internal arrangements of the Termini and intermediate Stations of Railways, whether for Passengers or Merchandize, and whether independent of, or connected with Inland Navigation.
31. Experiments on the Resistance to Railway Trains at different velocities.
32. The construction of Locomotive Engines; especially those modifications which enable additional power to be gained without materially increasing the weight, or unduly elevating the centre of gravity.
33. The construction of Railway Wheels and Axles, and the Bearings; treating particularly their ascertained duration and their relative friction.
34. The Electric Telegraph; the several modifications in its construction, and the various uses to which it has been applied.
35. Notice of the principal Self-acting Tools employed in the manufacture of Engines and Machines, and the effect of their introduction.
36. The most effective and best-adapted Machines for bruising, or crushing the Sugar Cane, and for separating the juice from the vegetable fibre.

37. The various modes of boring Artesian Wells, and the geological formations which have been found most productive of water.

38. Memoirs and accounts of the Works and Inventions of any of the following Engineers:—Sir Hugh Middleton, Arthur Woolf, Jonathan Hornblower, Richard Trevithick, William Murdoch (of Soho), and Alexander Nimmo.

Original Papers, Reports, or Designs, of these, or other eminent individuals, are particularly valuable for the Library of the Institution.

The communications must be forwarded, on or before the 31st of May, 1849, to the house of the Institution, No. 25, Great George-street, Westminster, where copies of this paper, and any further information may be obtained.

CHARLES MANBY, *Secretary.*

25, *Great George-street, Westminster*, 1849.

Notice.

It has frequently occurred, that in Papers which have been considered deserving of being read and published, and have even had premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers, or in the consequent discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

Extracts from the Minutes of Council, February 23rd, 1835.

"The principal subjects for which Premiums will be given are:—

"1st. Descriptions, accompanied by Plans and explanatory Drawings, of any work in Civil Engineering, as far as absolutely executed; and which shall contain authentic details of the progress of the work. Smeaton's Account of the Edystone Lighthouse may be taken as an example.

"2ndly. Models, or Drawings, with descriptions, of useful Engines and Machines; Plans of Harbours, Bridges, Roads, Rivers, Canals, Mines, &c.; Surveys and Sections of Districts of Country.

"3rdly. Practical Essays on subjects connected with Civil Engineering, such as Geology, Mineralogy, Chemistry, Physics, Mechanic Arts, Statistics, Agriculture, &c.; together with Models, Drawings, or Descriptions of any new and useful Apparatus, or instruments applicable to the purposes of Engineering or Surveying."

Instructions for Preparing Communications.

The communications should be written in the impersonal pronoun, and be legibly transcribed on foolscap paper, on the one side only of each page, leaving a margin of one inch and a half in width on the left side, in order that the sheets may be bound.

The drawings should give as many details as may be necessary to illustrate the subject, and should be to such a scale that they may be clearly visible, when suspended on the walls of the Theatre of the Institution, at the time of reading the communication, or enlarged diagrams may be sent for the illustration of any particular portions.

Papers which have been read at the Meetings of other Scientific Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper.

"No person shall publish, or give his consent for the publication of any communication presented, and belonging to the Institution, without the previous consent of the Council."

Excerpt Bye-Laws Inst. C. E., Sec. xiv., Clause 3.

ADDRESS OF JOSHUA FIELD, ESQ., PRESIDENT,

TO THE

ANNUAL GENERAL MEETING.

JANUARY 16, 1849.

I HIGHLY appreciate the kind expression of your thanks for very inadequate services; I am fully convinced of my inability to do justice to the position in which you placed me, and I receive your vote of thanks, more as a proof of your perception of my desire to perform the duties, than for the manner of their performance. On resigning the trust committed to me, I would offer my best thanks to the Vice-Presidents, Members, and Associates of the Council for their co-operation and strenuous support, as also to the Members of all classes of the Institution, and those Noblemen and Gentlemen who, being our visitors, have taken part in the discussions, and have given that frequent and numerous attendance which has characterized the meetings of the last Session, by which the chair was so well supported, and the objects of the Institution so well carried out. It has been highly gratifying not only to me, but to every well-wisher of the Institution, that the best feeling has prevailed at all our meetings, and the most perfect unanimity within the Council.

The subjects brought forward were for the most part of a practical character, and led to very interesting discussions, and it is to be hoped, that Members of all classes will not relax in the contribution of papers on subjects of general interest, particularly descriptions of works actually executed, demonstrating the difficulties that have been overcome. Such papers never fail to interest the meetings, whilst they are valuable examples for future practice, and record at the same time by whom, and in what manner, such works have been executed.

The report of the Council has given you a full detail of the state of the Institution, and of the proceedings during the last Session, so that it is unnecessary for me to make any remarks on that subject. In the financial statement, however, you have learned that there is

still a debt to be liquidated on the building account, to the amount of about £2500.

Although the total cost of repairing and fitting up this house, has considerably exceeded the sum at first contemplated, we have the satisfaction of possessing a good house, on a long lease, in substantial repair, admirably situated, and completely adapted in all its arrangements to the wants of the Institution.

The liquidation of this debt has anxiously occupied the attention of the Council, and I am happy to state, that without imposing a heavy burthen upon the Members, the object has been so far accomplished, that I may venture to say, the debt is nearly paid. This being arranged, it is hoped, that the publication of the Minutes of discussion will nearly keep pace with the meetings, and that country Members may be enabled, from a perusal of these records, to take the same interest, and receive the same advantages, as those who are resident in London.

The Obituary records the decease of several valuable Members, whose loss will be greatly felt. In addition to these gentlemen, the profession has lost another, who was considered a veteran and a hero in its ranks; I allude to Mr. George Stephenson, whose career could not be noticed in the Report, because he was not a Member of the Institution; he was, however, well known to us all, and not unfrequently joined in our discussions. He was also President of a kindred Society, "The Institution of Mechanical Engineers" at Birmingham. That Institution principally directs its attention to new inventions, in the mechanical and manufacturing processes, whilst the communications brought before us, are chiefly accounts of executed works in Civil and Mechanical Engineering. Thus, these two Societies embrace the whole science, and by combining their efforts, with mutual goodwill, and a perfect understanding, they may and do confer great benefits on the public.

Mr. Stephenson practised both as a Mechanical and a Civil Engineer, and attained equal eminence in both branches of the profession. The history of such a man, belongs not only to his own profession, but to the world, and even before his decease, several excellent Memoirs were published, which now possess deeper interest. I cannot, however, feel satisfied, that one who has acted such an important part in the great invention, or introduction of the period, and to which the attention of the most eminent Engineers has been so much devoted, for the last twenty years, and which has led to more important results, than any other discovery, either in ancient or modern times, should pass away without some special notice on

the part of this Institution. The Memoirs just alluded to depict the career of a man of remarkable natural genius, actuated by extraordinary mental and physical powers, combined with indomitable industry, perseverance, and integrity, and by the proper use of these powers, he is eventually seen to have overcome every difficulty, and to have raised himself from comparative obscurity, to the highest pinnacle of fame and fortune.

It is, however, in the important part he has acted in the railway system, that we are more particularly interested, and I am anxious to show how far he was concerned, in working out the great discovery, by which the success of that system has entirely depended.

The locomotive engine must be acknowledged to be the life-blood, or chief element, of the railway system, and those improvements which have imparted to it the wonderful velocity, now attained, deserve to be recorded. The first crude conception of the machine may be traced very far back; but the first authentic record of a full-sized locomotive engine, actually working, is about the year 1804; this engine was attached to a light open carriage, on the common road, and was exhibited at Lord's Cricket Ground; it was designed and constructed by Trevithick, who also made an engine about the same year, of different construction, which was employed on the Tredegar tram-road, for conveying minerals and iron, between the Tredegar iron-works and Newport, in South Wales. A short time afterwards another engine was tried in the neighbourhood of Newcastle-upon-Tyne. The subject was shortly after taken up by Stephenson and others, and engines were built, adapted for working on edge rails at the Wylam Colliery. Improvements were slowly introduced, and eventually locomotives, somewhat more in accordance with the present system, were generally used on the Stockton and Darlington Railway.

It must be observed, that up to this time, locomotives were of a rude and cumbrous construction, having a cylindrical boiler, with a fire-place inside, and a single longitudinal flue through it, terminating in a short chimney, upon which the fire wholly depended for its draught. From a boiler of this construction very little steam could be obtained, and a speed of about eight miles an hour absorbed all that could be generated, although the fire was so intense, that the flame generally extended beyond the top of the chimney, which was of course frequently red hot. Such was the condition of the locomotive when the Manchester and Liverpool Railway was projected, and although locomotive power was intended to be used, the maximum speed contemplated was only 12 miles an

hour; had not a new discovery been made, and a new life given to the locomotive, the Manchester and Liverpool Railway would simply have been employed in conveying bales of cotton and other goods, in the transit of coal, from the collieries to the shipping port, as other railways had previously been engaged.

At this period, however, a simple but most important improvement was introduced in the system of generating the steam; this was effected, by substituting for the single central tube, a cluster of longitudinal tubes of smaller diameter, between the fire-box and the chimney, through which the flame traversed, thereby vastly increasing the generating surface; and in order to obtain sufficient draught through these tubes, the steam, after passing from the cylinder, was conveyed to a perpendicular pipe in the base of the chimney, thus occasioning a powerful ascending current in the chimney; by this means an intense heat was obtained, steam was plentifully raised, and with this singular and unlooked-for advantage, that the faster the engine worked, the more the fire was urged, and thus the generation of steam was enabled to keep pace with the increased speed.

This was the real origin of the present railway system; and when this combination of the tubes, and the blast pipe was tried in the "Rocket" prize engine, on the Manchester and Liverpool Railway, the speed attained astonished every one, and completely altered the character of the whole enterprise. Instead of carrying goods, for which the railway was originally constructed, passengers only were conveyed, for some time, and the unexpected speed obtained, and the great passenger traffic which naturally followed, made that line the model upon which the present extensive railway system has been based.

"The Novelty," an engine by Braithwaite and Ericson, which also entered into the competition, had its fire urged by a blast of air through the grate; it also attained a considerable speed, but the simplicity and efficiency of the steam-blast and tubes was so obvious, as to decide the universal practice in their favour.

The system is now firmly fixed, and such is the importance of this adjunct, that if the best locomotive of the present day had its blast-pipe removed, it would not travel at above one-third of its actual speed. It is stated, that Mr. H. Booth, the then Secretary of the Manchester and Liverpool Railway, suggested the use of tubes in the locomotive boilers, to increase the evaporative surface. Clusters of tubes, having water within side them, had been previously used for boilers, and the waste steam from the engine had

also been turned into the chimney, sometimes for the purpose of conveniently disposing of it, in stationary engines, and also because it was said, even in Trevithick's time, to consume the smoke; but the "Rocket" was the first locomotive engine in which the tubes, with the fire passing through them, were used in conjunction with the blast-pipe in the chimney, to improve the draught.

This important and admirable combination was designed and executed by Mr. Stephenson, but great credit for working out the details must unquestionably be accorded to Mr. Robert Stephenson, who, at the period this triumph was achieved, was actively engaged with his Father, and he has subsequently introduced improvements, both in the principle and the manufacture of locomotives, which render his engines as nearly as possible perfect.

If, in endeavouring to pay this slight tribute to the late George Stephenson, it be considered, that I have dwelt too long upon this happy combination of the tubes and the steam blast, I must be pardoned, for it is really to this combination, that the success of the whole system must be attributed; and I do not find this important point sufficiently noticed in any history of the progress of railways.

It is not to be expected, that in our days, we shall again see such an unusual combination of circumstances, and of wants of the times, as those which developed the career of George Stephenson; but inasmuch as the acquisition of knowledge is now easier, and more channels are open for the beneficial display of that knowledge, the younger Members of the profession should be incited by his example, to attempt the perfecting of what he and others have so worthily introduced, and carried to a certain point. Fame and emolument may be theirs if they labour; and they have in the meetings of this Institution a fair field, where their labours will be quietly examined, and the public will fully appreciate the decision.

I cannot conclude without again offering my warmest thanks to the Council, the Officers, and the general body of Members, for their support during the past year, and expressing a hope that the ensuing Session may be more brilliant than any of its predecessors, and that the labours of the Institution may be universally appreciated and acknowledged.

ORIGINAL COMMUNICATIONS,

DRAWINGS, PRESENTS, &c.,

RECEIVED BETWEEN JUNE 30, 1847, AND JUNE 29, 1848.

ORIGINAL COMMUNICATIONS.

AUTHORS.

Alexander, W. No. 787. Description of an Apparatus for the prevention of Accidents at Pits. With one drawing, No. 4385.

Beanlands, A. No. 785. On Railway Junctions. With diagrams.

Browne, W. No. 798. Description of the Groynes formed on the South Rocks for constructing the new Docks at Sunderland. With a series of diagrams.

Cox, H. No. 791. On the Dynamical Deflection of Railway Girders.

Crampton, T. R. No. 794. On the construction of Locomotive Engines, especially those modifications which enable additional power to be gained, without materially increasing the weight, or unduly elevating the centre of gravity. With one drawing, No. 4391, and diagrams.

Dockray, R. B. No. 797. Description of the Camden Station of the London and North Western Railway. With eleven drawings, Nos. 4405 to 4415.

Fairbairn, W. No. 793. On Water-wheels, with ventilated Buckets. With four drawings, Nos. 4387 to 4390.

Gooch, D. No. 790. Observations on the Resistances to Railway Trains at different Velocities. With diagrams.

Grantham, R. B. No. 795. Description of the Abattoirs of Paris. With six drawings, Nos. 4399 to 4404.

Green, J. No. 780. Account of the recent Improvements in the Drainage and Sewerage of Bristol.

Harrison, J. T. No. 786. Observations on the Causes which are in constant operation, tending to alter the outline of Coasts, to affect the entrances of Rivers and Harbours, and to form Shoals and Deeps in the bed of the Sea. With diagrams.

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Jackson, G. B. W. No. 773. The Engineering of the Rhine, including a Translation of M. Van den Burgh's Paper, on the Improvements of the Moselle. With diagrams.

Lawrence, F. No. 792. An Account of the Blackfriars Landing Pier. With two drawings, Nos. 4392 and 4393.

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Mather, W. Description of Messrs. Mather and Co.'s Elastic Metallic Piston.

Mitchell, A. No. 783. On Submarine Foundations, particularly the Screw Pile and Mooring. With five drawings, Nos. 4419 to 4423.

Murray, Dr. J. No. 778. Remarks on the cause of the Fall of Arches of Brick-work.

Pickett, W. V. No. 776. On the Construction of Dwelling-houses of Iron.

Rankine, W. J. M. No. 782. Account of the effect of the Storm of the 6th December, 1847, on four Sea-walls or Bulwarks of different forms, as illustrating the principle of the Construction of Sea Defences. With diagrams.

Ransome, F. No. 774. On the production of Artificial Stone, with a Silica Base. With specimens of the material in different states.

Redman, J. B. No. 784. On the Alluvial Formations of the South-eastern Coasts of England. First section—Thames to Portland. With diagrams.

———— No. 777. Remarks on the formation and position of Dock Entrances, illustrated by the principal examples in the Port of London. With diagrams.

Richardson, J. No. 788. On the Coal of South Wales. With one drawing, No. 4384.

Richmond, J. No. 779. Description of an Improved Engine Counter.

Scott, M. No. 775. On a new method of discovering Leaks in Water Mains.

Tate, T. No. 781. On certain general formulæ relative to Railway Cuttings and Embankments.

ORIGINAL DRAWINGS.

DONORS.

Alexander, W. Plan and Section of Apparatus for the prevention of Accidents at Pits. No. 4385. Paper No. 787.

Brooks, W. A. Drawing showing the system of Mooring Vessels, with Mitchell's Screw Moorings, at Newcastle-on-Tyne. No. 4424. Paper No. 783.

Dockray, R. B. Plans, Sections, and Elevations of the Camden Station of the London and North Western Railway. Nos. 4405 to 4415. Paper No. 797.

Fairbairn, W. Plans and Sections of Fairbairn's improved Water-wheel. Nos. 4387 to 4390. Paper No. 793.

Grantham, R. B. Plans, Sections, and Elevations of the Abattoirs of Paris. Nos. 4399 to 4404. Paper No. 795.

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OF

CIVIL ENGINEERS.

SESSION, 1849.

January 9, 1849.

JOSHUA FIELD, President, in the Chair.

No. 793.—"On Water-wheels with ventilated Buckets."—By William Fairbairn, M. Inst. C.E.*

Since the time of Smeaton's experiments in 1759, little, or no improvement has been made in the principle on which water-wheels have been constructed. The substitution, however, of iron for wood, as a material for their construction, has afforded opportunities for extensive changes in their forms, particularly in the shape and arrangement of the buckets, and has given, altogether, a more permanent and lighter character to the machine, than had previously been attained with other materials. A curvilinear form of bucket has been generally adopted, the sheet-iron of which it is composed affording facility for being moulded, or bent into the required shape.

From a work entitled "Méchaniques et Inventions approuvées par l'Académie Royale des Sciences," published at Paris in 1735, it appears, that previous to the commencement of the last century, neither the breast nor the overshot water-wheels were much in use, if at all known, and at what period, and by whom they were introduced, is probably equally uncertain. The overshot wheel was a great improvement, and its introduction was an important step in the perfecting of hydraulic machines; but the breast-wheel, as now generally made, is a still further improvement, and is probably better calculated for effective duty, under the circumstances of a variable supply of water, to which almost every description of

* The discussion on this Paper extended over a portion of two evenings, but an abstract of the whole is given consecutively.

water-wheel is subjected. It is not the object of the present paper to enter into the dates and nature of the improvements which have taken place during the last and the present centuries. Suffice it to observe, that the breast-wheel has taken precedence of the overshot-wheel, probably not so much from any advantage gained by an increase of power, on a given fall, as from the increased facilities which a wheel of this description, having a larger diameter than the height of the fall, affords for the reception of the water into the chamber of the bucket, and also for its final exit at the bottom.

Another advantage of the increased diameter is the comparative ease with which the wheel overcomes the obstruction of backwater. The breast-wheel is not only less injured from the effects of floods, but the retarding force is overcome with greater ease, and the wheel works for a longer time and to a much greater depth in backwater.

The late Dr. Robinson (Professor of Natural Philosophy in the University of Edinburgh), in treating of water-wheels, says, "There frequently occurs a difficulty in the making of bucket-wheels, when the half-taught millwright attempts to retain the water a long time in the buckets. The water gets into them with a difficulty which he cannot account for, and spills all about, even when the buckets are not moving away from the spout. This arises from the air, which must find its way out to admit the water, but is obstructed by the entering water, and occasions a great sputtering at the entry. This may be entirely prevented by making the spout considerably narrower than the wheel. This will leave room at the two ends of the buckets for the escape of the air. This obstruction is vastly greater than one would imagine; for the water drags along with it a great quantity of air, as is evident in the water-blast as described by many authors." *

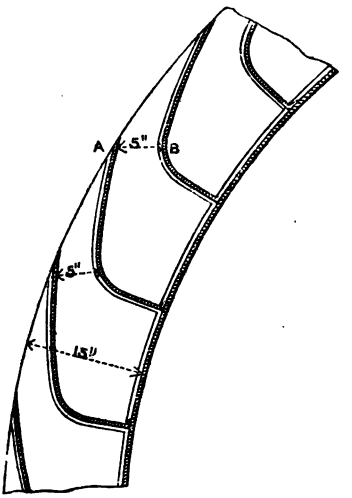
Such were the opinions of one of our first writers on Mechanical Philosophy; but the evil has been subsequently much increased by attempting to form a bucket which should carry the water down to the lowest point of the fall. In these attempts the opening became so contracted as to prevent the free admission of the water from the cistern into the buckets, and its free discharge at the bottom of the wheel.

In the construction of wheels for high falls, the best proportion of the opening of the bucket is found to be nearly as five to twenty-four; that is, the contents of the bucket being twenty-four cubic feet, the area of the opening, or entrance for the water would be five square

* *Vide* Robinson's Mechanical Philosophy, vol. ii. p. 598.

feet. In breast-wheels which receive the water at a height of 10° to 12° above the horizontal centre, the ratio should be nearly as eight to twenty-four, or as one to three, as shown in Plate II, Fig. 3. With these proportions, the depth of the shrouding is assumed to be about three times the width of the opening, or three times the distance from the lip to the back of the bucket, as from A to B, Fig. 1, the opening being five inches, and the depth of the shroud fifteen inches.

Fig. 1.



For lower falls, or in those wheels which receive the water below the horizontal centre, a larger opening becomes necessary for the reception of a large body of water, and its final discharge, as shown in Plate I, Fig. 3.

In the construction of water-wheels, it is requisite, in order to attain the maximum effect, to have the opening of the bucket sufficiently large to allow an easy entrance and an equally free escape for the water, as its retention in the bucket must evidently be injurious, when carried beyond the vertical centre.

Dr. Robinson further observes, "There is another and very serious obstruction to the motion of an overshot, or bucketed wheel. When it moves in backwater, it is not only resisted by the water when it moves more slowly than the wheel, which is very frequently the case, but it lifts a great deal in the rising buckets. In some particular states of backwater, the descending bucket fills itself completely

with water, and in other cases it contains a very considerable quantity, and air of common density; while in some rarer cases, it contains less water, with air in a condensed state. In the first case, the rising bucket must come up filled with water, which it cannot drop till its mouth gets out of the water. In the second case, part of the water goes out before this; but the air rarifies, and therefore there is still some water dragged or lifted up by the wheel, by suction, as it is usually called. In the last case, there is no such back-load on the rising side of the wheel, but (which is as detrimental to its performance) the descending side is employed in condensing air; and although this air aids the ascent of the rising side, it does not aid it so much as it impedes the descending side, being (by the form of the bucket) nearer to the vertical line drawn through the axis.*

These were the difficulties under which the Millwrights of Dr. Robinson's time laboured; and the remedy which they applied (and which has since been more, or less continued) was to bore holes in what is technically called the "start" of the bucket. This was the only means adopted for removing the air from the buckets of overshot-wheels, in order to facilitate the admission and emission of the water. In lower falls, where wheels with open buckets were used, or straight float-boards radiating from the centre, large openings were made in the sole planking, exclusive of perforations in each bucket, in order to relieve them from the condensed air. The improved construction of the present time is widely different, the buckets being of such a shape as to admit the water, at the same time that the air is making its escape.

During the early part of 1825, and the two succeeding years, two iron water-wheels, each of one hundred and twenty H. P. were constructed in Manchester, for Messrs. James Finlay and Co., of the Catrine Works, under the auspices of the late Mr. Buchanan, and also for the same Company at Deanston, in Perthshire, of which firm Mr. James Smith (Deanston) was then the resident partner. Those wheels are still in operation, and taking them in the aggregate, they probably rank, even at the present day, as some of the most powerful and the most complete hydraulic machines in the kingdom. The construction of these wheels, and others for lower falls, first directed the Author's attention to the ingress and egress of the water, and led to the improvements which have since been introduced by him.

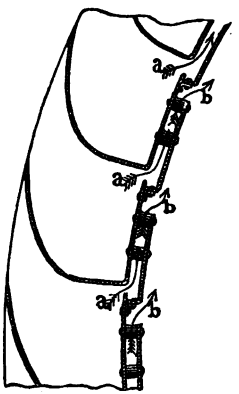
The object of these modifications may be generally stated to

* *Vide* Robinson's Mechanical Philosophy, vol. ii. p. 599.

have been, for the purpose of preventing the condensation of the air, and for permitting its escape, during the filling of the bucket with water, as also its re-admission during the discharge of the water into the lower mill-race.

Shortly after the construction of the water-wheels for the Catrine and Deanston Works, a breast-wheel was made and erected, for Mr. Andrew Brown, of Linwood, near Paisley. In this it was observed, when the wheel was loaded, and in flood waters, that each of the buckets acted as a water-blast, and forced the water and spray, to a height of six, or eight feet above the orifice at which it entered. This was complained of as a great defect, and in order to remedy it, openings were cut in the sole-plates, and small interior buckets were attached to the inner sole, as shown at *b*, *b*, *b*, Fig. 2. The air in this case made its escape through the openings *a*, *a*, *a*, *a*, into the inner bucket, and passed upwards, as is shown by the arrows, through *b*, *b*, *b*, into the interior of the wheel. By these means it will be observed, that the buckets were effectually cleared of air, whilst they were filling, and that during the obstructions of back-water, the same facilities were afforded for its readmission, and the discharge of the water, contained in the rising buckets. The effect produced by this alteration, could scarcely be credited, as the wheel not only received, and parted with the water freely, but an increase of nearly one-fourth of the power was obtained, and the wheel, which still remains as then altered, continues, in all states of the river, to perform its duty satisfactorily.

Fig. 2.



The amount of power gained, and the beneficial effects produced upon Mr. Brown's wheel, induced a new and still greater improvement in the principle of construction; the first wheel erected on this, which has been called the "ventilated" principle, was one designed for Mr. Duckworth, at the Handforth Print Works, near Wilmslow, in Cheshire. This wheel was identically the same as that shown in Plate I, and was started in 1828. The improvement of the breast-wheel, with the close sole and ventilated buckets, as shown in Plate II, immediately followed.

Close bucketed wheels labour under great difficulties, when re-

ceiving the water through the same orifice at which the air escapes, and in some wheels, the forms and construction of the buckets are such, as almost entirely to prevent the entrance of the water, and to deprive the wheel of half its power. These defects may be easily accounted for, where the water is discharged upon the wheel in a larger section than the opening between the buckets, as under such circumstances, the air is suddenly condensed, and re-acting by its elastic force, throws back the water upon the orifice of the cistern, and thus allows the buckets to pass without their being more than half filled. Several methods have been adopted for relieving them of the air; the most common plan is, by cutting holes, as before mentioned, in the sole plates, close to the back of the buckets, or else making the openings between them much wider, in order to admit the water, and at the same time to allow the air to escape. All these remedies have been more or less effective; but they labour under the objections of a great waste of water and much inconvenience, by the water falling from the openings, down upon the lower part of the wheel, exclusive of the puffing and blowing when the bucket is filling.

Other remedies have been applied, such as circular tubes and boxes attached to the sole-plates, which extending upwards, furnish openings into the interior of the wheel for the air to escape; but these, like many other plans, have been, to a certain extent, unsuccessful, owing to the complexity of their structure, and the inadequate manner in which the objects contemplated were attained. In fact, in wheels of this description it has been found more satisfactory to submit to acknowledged defects, than to incur the trouble and inconvenience of partial and imperfect remedies.

In the improvements made by the Author, these objections are to a great extent removed, and a thorough system of ventilation has been effectually introduced. Before entering upon the description of this new principle of ventilation, it is necessary to remark, that in climates like Great Britain and Ireland, where the atmosphere is charged with moisture for six, or seven months in the year, it is no uncommon occurrence for the rivers to be considerably swollen, and the mills depending upon water, are either impeded, or entirely stopped by back-water; while at other times, a deficiency of rain reduces the water power below what is absolutely required to drive the machinery. On occasions of this kind, much loss and inconvenience is sustained, particularly in mills exclusively dependant

upon water as a motive power, and where a number of workpeople are employed.

On the outskirts of the manufacturing districts, where the mills are more, or less dependant upon water, these inconveniences are severely felt; and in some situations these interruptions arise as frequently from an excess of water, as from a deficiency in the supply. To remedy these evils, reservoirs have been formed, and wheels have been constructed to work in floods; but, although much has been accomplished, for diminishing these injurious effects, and giving a more regular supply in dry seasons, yet the system is still imperfect, and much has yet to be done, before water can be considered equal, as a motive power, to the steam-engine, which is always available, where the necessary fuel is at hand. It is therefore obvious, that any improvement in the construction of water-wheels, whereby their forms and requirements may be better adapted to meet the exigencies of high and low waters, will contribute much to the efficiency and value of mills, situated upon rivers, and subjected to the changes before alluded to.

Ventilated Water-wheels as adapted to low Falls.

The first wheel constructed upon the ventilated principle was erected at Handforth in Cheshire, in the summer of 1828; it proved highly satisfactory to the proprietors, Messrs. Duckworth and Co., and gave such important results, as to induce its repetition, without variation, in cases where the fall did not exceed the semi-diameter of the wheel.

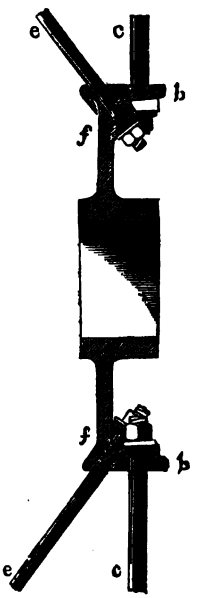
Plate I. represents a front and side view of a water-wheel, with ventilated buckets, adapted to falls of less than half the diameter of the wheel. Portions of the side shrouding and segments are removed, in order to show a section of the buckets, and the position in which they are placed to receive the water.

A, is the axle, or ribbed shaft, supporting the two centre discs C, C, from which the wheel is suspended; B, B, are projecting sockets, into which are inserted the malleable iron arms, *a*, *a*, and the diagonal stays or braces *b*, *b*, varying respectively from two inches to one and three-quarters inch in diameter. D, represents the buckets, with the shuttle, which regulates the supply of water, and which is made to slide downwards; F, the termination of the stone-breast, and E the tail-race, or point of discharge.

In the earlier construction of iron suspension wheels, by the late Mr. J. C. Hewes, the arms and braces were fixed to the centres,

by screws and nuts upon their ends, as shown in Fig. 3. The arms *c*, *c*, passed through the rim *b*, *b*, and the braces *e*, *e*, which traverse the angle of the rim at *f*, *f*, are, as nearly as possible, in the position and form adopted by Mr. Hewes. This arrangement, although convenient for tightening up the arms and braces, was liable to many objections, arising from the nuts becoming loose, and the consequent difficulty of keeping the wheels true to the circle, and the arms and braces in an uniform state of tension; gibs and cotters were therefore substituted for the nuts and screws, and since their introduction into the large wheels of the Catrine Works, Ayrshire, the objections have been removed, and the arms and braces are now not only perfectly secure, but the periphery of the wheel is retained in its true and correct form. It will not, therefore, be necessary further to explain this part of the structure, as the plates are sufficiently explicit, to give a correct idea of all the parts.

Fig. 3.



Having noticed the obstructions offered to the entrance of the water, into buckets of the usual form, and the consequent loss, which ensues from its retention upon the wheel, after its powers of gravitation have ceased, it may be necessary to show the means whereby those defects were removed, and also to exhibit the relation existing between the breast and the undershot wheels. These terms have, however, become nearly obsolete, as every description of water-wheel, may now be properly called a breast-wheel, and in every fall, however low, it is generally found advantageous for the water to act by gravitation and not by impulse, as during the earlier periods of the industrial arts.

If the process of filling and emptying the buckets of the wheels shown in Plates I. and II., be traced respectively in each, it will be found, that in the event of a large body of water, being discharged into the buckets at D, Plate I, Fig. 1, it could not be filled, if the opening at *g* was closed, and the air was prevented from escaping in that direction. Under these circumstances the air would be compressed and pent up in the bucket, and the water be prevented from entering, or be blown out, as already described.

Now this is not the case, when they are properly ventilated, as a perfectly free passage is constantly open for the escape of the air, in the direction of *g*, and an equally free entrance is again afforded for the water at D.

This principle of construction is however more clearly shown upon a large scale, in Plate I. Fig. 3, the passage for the escape of the air being represented by the direction of the arrows through the openings *e*, *e*, and *e*, and also the connexion of the buckets with each other, by rivets and tubular blocks, as shown in the same plate. When a wheel of this description is heavily loaded, a small quantity of water will sometimes escape along with the air, above the lip of the outlets *g*, *g*, Fig. 1, into the interior of the wheel; but that is of little consequence, as it is again received into the buckets, as it falls upon the wheel, and even this defect may be removed, by carrying the edge of the plate higher upon the sole of the upper bucket. For low falls, the length of the tail side of the buckets, as given in Plates I. and II., will however be found in practice, quite sufficient, either as regards the economy, or the distribution of the water.

Having treated of the entrance of the water into the buckets, it is necessary to describe the facilities, afforded by this construction, for its discharge. A quick and easy outlet for the water, when no longer required upon the wheel, is as important as an expeditious inlet, and it is evident, that every drop of water, which is carried by the wheel beyond the vertical line of the centre, at E, Fig. 1, is so much useless absorption of its power; moreover, in the construction of the bucket, for the reception of the water, strict reference should also be had, to its free and uninterrupted discharge. Another main point of consideration is the distance to which the water is carried, by its momentum, or centrifugal action, when leaving the wheel, and it will be found advantageous to effect the discharge of the water, as soon as the bucket passes the lower edge of the stone breast at F. This discharge being seldom accomplished in time, in the old wheels, was a serious counterpoise to the power of the wheel, as the ascending buckets carried with them, portions of the water to a considerable height, on the opposite side of the vertical centre. In the improved construction, this defect is obviated; as the opening which allows the air to escape, during the filling of the bucket, re-admits it with the same facility during the discharge; there cannot, consequently, be any formation of a partial vacuum, and the wheel not only works easily, but to a much greater depth in the back-water. It has also been

found necessary, in order to facilitate the escape of the water, to terminate the breast, at a distance of about ten inches from the vertical centre, and always to have a depth of from eighteen inches to two feet of water, under the bottom of the wheel.

These are considerations of some value, as the abrupt termination of the breast, at the point F, admits of a much quicker discharge of the water from the buckets, and the increased depth of the tail-race, gives room for its escape, after it has passed from the wheel. In fact, the benefits arising from this form of breast, and tail-race, are so great, that they should be strictly enforced, where it is desirable to have the full and effective use of the fall. In the erection of water-wheels, these principles should never be lost sight of, and instead of a shallow tail-race, with the water running from the wheel, at a rate of from six feet to eight feet per second, as is frequently the case with the old wheels, the current should be scarcely perceptible, and the water should flow steadily, and as smooth as in a deep canal.

It would, perhaps, be difficult to describe with accuracy, the properties and proportions of these improvements, without a long series of costly experiments, upon a large scale; and in order to make the comparison perfect, the new and old forms of water-wheels, should be placed in juxta-position, each having a proportionate load, and working as nearly as possible, under the same conditions, both as to the fall and the supply of water. Under these circumstances, the great difference, which exists between the one kind and the other, would become apparent, not only as respects superior economy, but also the perfect ease with which the ventilated wheel overcomes the resistance of the load, and the obstructions of backwater, to which wheels are subject, during floods.

On some future occasion an opportunity may present itself, for returning to this subject, when the superiority of water-wheels, with ventilated buckets, may be confirmed by more detailed experiments, and when the relative forms of wheels and buckets, may be respectively established. For the present, it will suffice to observe, that the wheel already described and exhibited in Plate I., will be found in practice, exceedingly effective, and probably the best adapted, with certain modifications, for falls not exceeding ten feet in height.

Breast Wheels, with close Soles, and Ventilated Buckets.

The preceding statements have been principally confined to the form of bucket, and description of water-wheel, adapted for low

falls. It will now be necessary to describe the best form of breast wheels for high falls, or those best calculated for attaining a maximum effect, on falls varying from one-half to three-fourths of the diameter of the wheel. This is a description of water-wheel in common use, and is generally adopted for falls which do not exceed eighteen feet in height, and, in most cases, is preferable to the overshot wheel. It possesses many advantages over the undershot wheel, and its near approximation to the duty, or labouring force, of wheels of that description, renders it applicable, in many situations, especially where the fall does not exceed eighteen, or twenty feet, and where the wheel is exposed to the obstructions of back-water. In the latter case, wheels of larger diameter are best adapted, and provided sufficient capacity is left in the buckets, such wheels may be forced through the back-water, without diminution of speed. Every wheel of this kind should have capacity in the buckets, to receive a sufficient quantity of water, to force the wheel, at full speed, through a depth of five or six feet of back-water; and if these provisions are made, a steady uniform speed, under every circumstance of freshes and flood-waters, may be attained.

A water-wheel, of this kind (Plate II.), of one hundred H.P., was constructed for T. Ainsworth, Esq., of Cleator, near Whitehaven, about four years back, for driving a flax-mill; it is twenty feet in diameter, twenty-two feet wide inside the bucket, and twenty-two inches deep on the shroud. It has a close riveted sole, composed of No. 10 wire gauge iron plate, and the buckets are ventilated from one to the other, as shown on the large scale at Fig. 3. The fall is seventeen feet, and the water is discharged upon the wheel, by the circular shuttle A, which is raised and lowered by a governor, as circumstances require. By this arrangement, the whole height of the fall is rendered available, and the water in dry seasons, may be drawn down from three to four feet, in order to afford time for the dam to fill, during the periods of rest, either during the night, or at meal-times.

In this wheel, the power is taken from each side, by two pinions working into the internal segments B, B, and these again give motion to shafts, and wheels at C, C, which communicate with the machinery of two different mills, at some distance from each other.

The position of the pinion, or the point where it "gears" into the segments, is of some importance in every water-wheel, but more particularly in those constructed on the suspension principle, which, upon inspection, will be found but indifferently prepared to resist a torsive strain, when the power is taken from the opposite side

of the loaded arc of the wheel. Water-wheels of this construction, with malleable iron rods only two inches in diameter for their support, could not resist the strain; but would twist round upon the axle as a fixed centre of motion.

It therefore becomes necessary, on every occasion, to take the power from the loaded side of the wheel, and as near the circumference as possible, in order to throw the weight of the water upon the resistance of the pinion, and that such resistance, shall be at the point of the greatest velocity.

In the old water-wheels, where the power was generally taken from the axle, the whole of the force first passed through the arms to the axle, and afterwards by a pit-wheel, or some other multiplier of speed, to the machinery in the mill. Now, in the improved wheels, this is not the case, as the arms, braces, and axle, have only to sustain the weight of the wheel, and to keep it in shape, and by the power being taken from the circumference, considerable complexity of the transmission of the power, is avoided; a great saving is also effected, when the speed required is greater than that of the wheel.

It has already been shown, that this description of wheel has a close sole, and on reference to the figure, it will be found, that the tail-ends of the buckets *a*, *a*, *a*, Fig. 3, are turned up at a distance of two inches from the back of the sole plate, and running parallel with that part, terminate within about two inches from the bend of the upper bucket. The object of this construction is obvious, as the water in passing through the openings between the buckets, drives the air before it in the direction of the arrows at *a*, *a*, *a*, into the bucket above, and so on in succession, till each bucket is filled as it passes the aperture of the cistern, from which the water flows upon the wheel.

Irrespective of the advantages of clearing the buckets of air, additional benefit is obtained, by the facility with which the water is discharged, and the air again admitted, at the bottom of the fall, during the period of the emptying of the bucket into the tail-race.

This is strikingly illustrated where the wheels labour in back-water, as the ventilated buckets rise freely above the surface, and the communication being open from one to the other, the action is rendered perfectly free, at almost any depth to which the wheel may be immersed.

In breast-wheels constructed for falls of twenty-five feet, or upwards, the stone breast is not required, as the buckets are formed

with narrow openings, and the lip being extended nearer to the back of the following bucket, the water is retained much longer upon the wheel. Under these circumstances a stone breast is of little, or no value, when attached to a wheel with close buckets, on a high fall.

The construction of the breast-wheels, as above described, is almost exactly similar to that for the lower falls; malleable iron arms and braces being common to both, as also the axle, shroud, and segments. These when duly proportioned and properly fitted to each other, form one of the strongest, and probably the most permanent structures that can be attained, in works of this description.

Common Breast-wheel (not ventilated), as constructed by Messrs Fairbairn and Lillie, between the years 1825 *and* 1827.

These wheels were executed upon the plan of the overshot, or breast-wheel, taking the water at an elevation nearly equal to that of its height. Four wheels of this description were constructed for Messrs. James Finlay and Co., for a fall of thirty-two feet, at Deanston, in Perthshire, and two others, for the same firm, at the Catrine Works, in Ayrshire, on a fall of forty-eight feet. Taking into consideration the height of the fall, the Catrine water-wheels, both as regards their power and the solidity of their construction, are, even at the present day, probably among the best and most effective structures of their kind in existence. They have now been at work upwards of twenty years, during which time they have required no repairs, and they remain nearly as perfect as when they were erected.

It was originally intended to have erected four of these wheels at the Catrine Works, but only two have been constructed; preparations were, however, made for receiving two others, in the event of an enlargement of the reservoirs in the hilly districts, and more power being required for the mills. This extension has not as yet been wanted, as these two wheels are equal to two hundred and forty H. P., and are sufficiently powerful, except in very dry seasons, to turn the whole of the mills.

On referring to Plate 3, it will be observed, that in the original design the water-wheels were so placed and arranged, as to communicate their motion to a series of connecting cross shafts, and by means of large spur-wheels and pinions, to transmit the united power of the water-wheels through large horizontal shafts to a cotton-

mill at a considerable distance, and also by means of a pair of large bevil-wheels and shafts, to keep in motion another mill of equal magnitude in another direction.

These water-wheels are fifty feet in diameter, ten feet six inches wide inside the bucket, and fifteen inches deep on the shroud; the internal spur segments are forty-eight feet six inches diameter, three inches and a quarter pitch, and fifteen inches broad on the cog; the large spur-wheels are eighteen feet two inches and a-half in diameter, three inches and a quarter in the pitch, and sixteen inches wide on the cog; and the pinions are the same width, and pitch, but are five feet six inches in diameter; the large bevil wheels are seven feet in diameter, three inches and a half in the pitch, and eighteen inches broad on the cog, their proportions being calculated to convey the united power of all the four water-wheels, should the original design ever be completed.

The water for the supply of the wheels, is conveyed from the river Ayr, in a canal and tunnel, and from thence along the side of a rising bank, to the wheel-house. From this point it is conveyed to the water-wheels by a large sheet iron trough, supported on iron columns.

When viewed from the entrance, the two wheels already erected have a very imposing effect, each of them being elevated upon stone piers; and as the whole of the cisterns, sluices, winding apparatus, galleries, &c., are considerably elevated, they are conveniently approached in every part. Under the wheels, is a capacious tunnel, terminating at a considerable distance down the river.

The plates give the details of the pen-trough for conveying the supply of water to the wheels, and show the position of the pinions, which gear into each main driving-wheel near the point of gyration. The shuttle and the method of regulating the water to obtain uniform velocity are also given, but as these must vary with the locality in which the water-wheels are established, it is not necessary to enter minutely into a description of them.

Water-wheels, on a principle introduced by M. Poncelet, have attained some considerable reputation on the Continent, and as the author has constructed one of them for Mr. De Bergue, it is necessary to allude briefly to the peculiarities it possesses.

The buckets are of a curvilinear form, and are quite open at the back, without any sole plate; so that they are perfectly ventilated. The water impinges upon them at nearly the lowest point of the wheel, the shuttle being arranged to draw upwards, and as the water enters,

by Messrs. Fairbairn & Lillie — 1847.

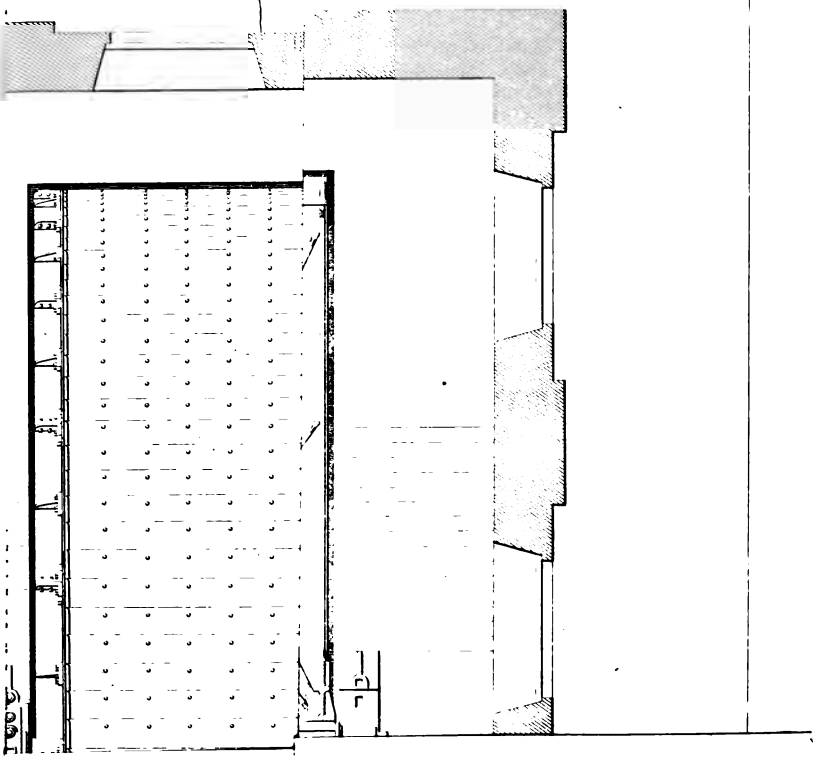
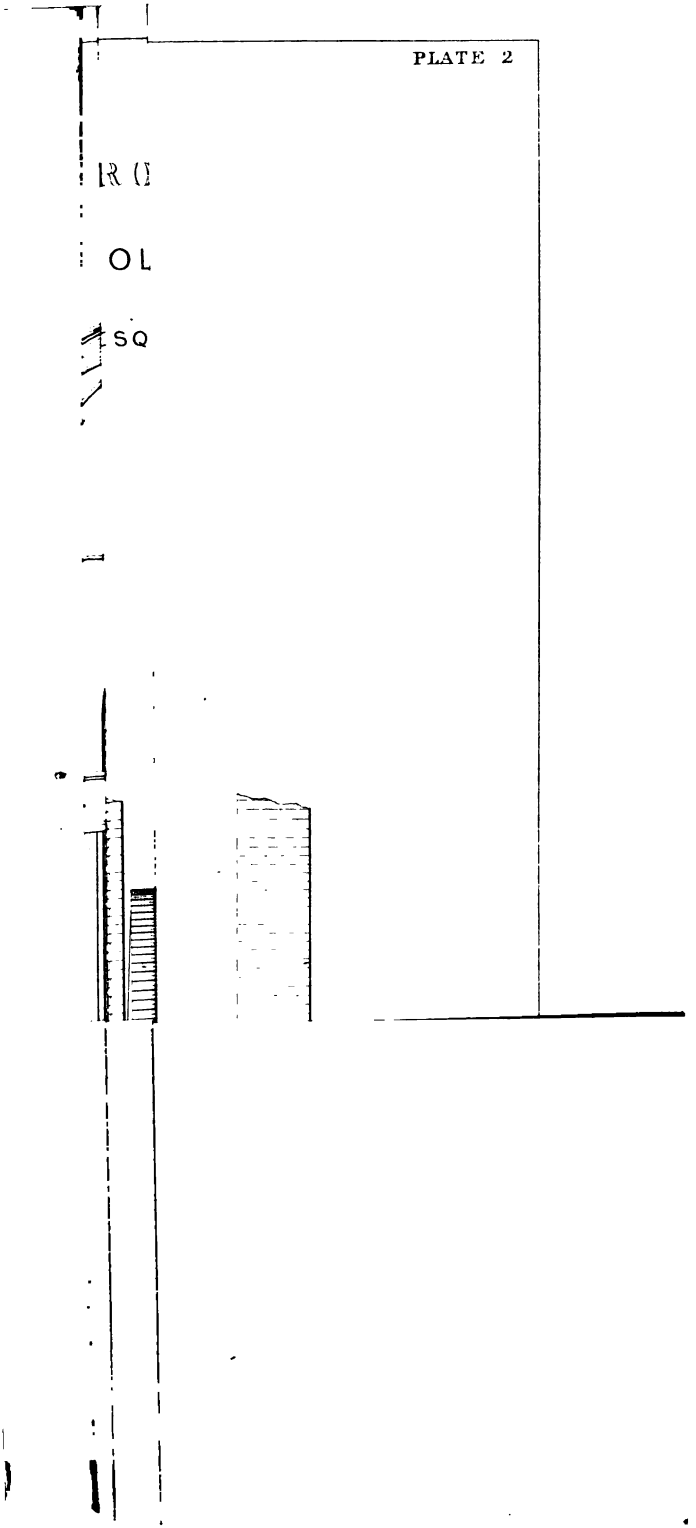


PLATE 2



W

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it follows the inside cavity of the bucket, rises and falls over into the next in succession, and so on. By this system the force of the water is expended on the wheel itself, instead of losing much of its power in rushing along through the wheel-race, as generally occurs in even well made undershot wheels.

M. Poncelet has treated this subject at such length in his able work on water-wheels, that it is not necessary here to enter into further details; but it may be observed, that a practical improvement might be effected, by terminating the lower stone platform of the race somewhat short of the vertical line of the centre of the wheel, as the escape of the water would be facilitated, and the ascending buckets would be more easily relieved of their contents; this is a point of such importance for all wheels, that it must equally apply to this form.

In this Paper, the turbine, with the improvements recently introduced in it by Fourneyron, Zuppinger, Whitelaw, and others, has been entirely omitted. There are many published statements relative to these improvements, but its limited employment in this country, up to the present time, scarcely renders it necessary to refer to it. It is however asserted that as much as ninety to ninety-two per cent., have been obtained from M. Fourneyron's turbine, but that gentleman, in a recent visit to this country, kindly furnished the Author with data taken from several of his machines, which reduce the duty to a mean of seventy-two per cent. M. Zuppinger and Mr. Whitelaw, do not claim a higher duty in their machines, the average being from seventy to seventy-four per cent. upon the theoretical value of the fall.

Mr. RENNIE said, Mr. Fairbairn's experience in the construction of water-wheels, was so great, and the general remarks of the Paper were so accurate, that little could be added, and he was grieved to disagree with any point in it; but he could not accord with the statement of few improvements having been introduced since the time of Smeaton. Mr. Rennie must claim some merit for his late Father, who had carefully studied both the theory and practice of water-wheels, and he would not permit Mr. Fairbairn to detract from his own merit, as he was universally acknowledged to be at least one of the most successful constructors of these machines.

The late Mr. Rennie introduced the system of laying the water on to the wheel in a thin stream, not exceeding ten inches in depth. In addition to this, and for the purpose of taking the utmost advan-

tage of the fall, he used the curved moveable shuttle, and at the same time tried various curves for the buckets. It appeared, that Mr. Fairbairn had directed his attention to nearly the same points, as there was great similarity in the machines, he having apparently taken the subject up where Mr. Rennie had left it, and the excellent result appeared in the statements contained in the Paper.

Poncelet's experiments on this subject showed, that in some wheels constructed with curved buckets, but without sole-plates, and receiving the water almost like undershot wheels, an advantage of ten per cent. over the ordinary forms could be attained.

The experiments of the Franklin Institute, made upon large wheels, were perhaps the most valuable. The greatest result obtained was, he believed about sixty per cent., with a velocity of eight feet per second.

As the opinion of Professor Robinson had been quoted, it might not be uninteresting to state, that on one occasion he was consulted by his former pupil, the late Mr. Rennie, as to the best form and dimensions of a water-wheel, and that the result was a complete failure; proving that his practice was not as good as his theory.

Sometime since it was expected, that the turbine would, in a great measure, supersede water-wheels; but, however well they might be adapted for peculiar situations, they had not been generally introduced. Fourneyron brought the idea from Germany, and materially improved upon the construction, until, as he stated, about seventy-five per cent. of power was obtained from them; but Mr. Rennie had never yet seen any turbine perform that amount of duty.

Whitelaw's wheel followed, and was stated to have attained about the same power. These machines, however, were both difficult of construction, and did not appear to make progress among Engineers.

Mr. FAIRBAIRN regretted, that he had not read an account of the improvements of the late Mr. Rennie, both before he had constructed the wheels, and when he wrote the Paper, as he could not have failed to benefit by following in the steps of so worthy a predecessor.

The turbine had been noticed very cursorily in the Paper, because the subject had been nearly exhausted in the excellent Paper by Mr. Lewis Gordon,* and because that machine had really been but little employed in this country, and not very extensively on the Continent. He had constructed one for M. Fourneyron, which had been sent to Italy, and was stated to have done good work. He had

* Vide Minutes of Proceedings Inst. C. E. 1842, vol. ii. p. 92.

also made one for Mr. Whitelaw, which had been erected in Yorkshire, for a fall of one hundred and twenty feet. It was at first two feet in diameter, and made about four hundred revolutions per minute, at which speed about thirty per cent. of the power was obtained; it was then altered to two feet six inches diameter, when about fifty per cent. was arrived at; and he believed that other alterations had still further improved its action. Some practical difficulties always occurred, such, among others, as the means of lubricating the main vertical spindle under water, which, for ordinary cases, tended to induce a preference for good water-wheels.

Mr. Whitelaw had asserted, that with a good fall, as much as seventy or seventy-five per cent. of power could be obtained; but M. Fourneyron did not anticipate more than seventy-two per cent.

Mr. Fairbairn had seen abroad a kind of turbine working horizontally, which received the water, through pipes, from a very high fall, into curved buckets, upon the two opposite extremities of its diameter; the velocity was very considerable, and the power gained was stated to be great.

Mr. Croker said, one of the most successful of M. Fourneyron's turbines was erected at St. Blasieu, in the Black Forest, upon a fall of three hundred and fifty feet. The diameter was twelve inches and a half; and when the sluice was open about one-third of an inch, the machine made two thousand two hundred and fifty revolutions per minute, with an expenditure of water not exceeding sixty cubic feet. The supply of water was derived from streams amongst the surrounding hills, and being collected into a reservoir, distant upwards of three-quarters of a league from the turbine, was thence conveyed to it in cast-iron pipes, eighteen inches in diameter. The turbine was used for driving a spinning factory, containing eight thousand water spindles, with the roving frames, carding engines, and all other necessary machinery. The duty of the machine was calculated, from experiment, to be equal to seventy per cent. of the water expended.

Mr. Glynn said, his custom in the construction of water-wheels had been to obtain free egress for the air, by simple openings through the sole-plate, into the interior of the wheel. The contrivance for conveying the air upwards adopted in the wheels which had been described, was a decided improvement, and would tend materially to that regular filling and emptying of the buckets, without which uniformity of motion could not be insured, and for many of the fabrics manufactured by water power that regularity was essential. The ordinary velocity of the wheel was about six feet per second; and with respect to the per centage of power ob-

tained, when the water fell upon the wheel without impulse, and left it without velocity, he conceived that nearly all the power was used.

He admired the details of construction of Mr. Fairbairn's wheels, particularly the arrangement for taking the lift on the loaded side of the wheel, and thus making the axle only the means of retaining the wheel in its place.

Mr. FAIRBAIRN stated, in answer to Captain Moorsom, that he considered the form of the bucket did contribute materially to the regularity of motion. It was important to carry the water down as near to the vertical centre as possible, so as to get the best effect from it, and yet to begin to part with it, as soon as that line was passed. That form was also found to fill better, and waste less water in times of drought, whilst it worked very easily, and without injury from back water in times of flood.

The ventilating wheels were not so essential for very high falls; they would be more expensive, and as the measure of all benefit was the cost, he should not consider them indispensable for high falls with abundance of water.

Mr. BEARDMORE thought, that there was scarcely a situation in Cornwall to which this kind of wheel was applicable, as all the falls were very high. The wheels in that district were chiefly employed for working stampers, or for pumping. In neither case was regularity of action at all necessary; for pumping an exertion of force was essential to raise the heavy plunger rods, and then the wheel might run at any velocity during the other portion of its revolution, and before the next stroke was made, power was accumulated, by the extra filling of these particular buckets, the others possibly not having been more than half filled; the millwright, therefore, gave plenty of bucket room, and ventilation was afforded at the extremities.

Mr. WICKSTEED considered the wheels in Cornwall and those in Lancashire were so differently employed, that no useful comparison could be drawn between them. He thought, however, that no doubt could exist as to the advantages of Mr. Fairbairn's improvements, where steadiness of action, and the economical use of water, were required. He apprehended that some difficulty might occur in times of flood; but the form of the buckets was calculated to meet, to some extent, even that objection. Great attention appeared to be deservedly given to the angle formed by the bucket with the periphery, and he conceived that it was a question of importance, particularly in relation to the amount of strain upon the axis.

Mr. Wicksteed had tried experiments upon large-sized water-wheels, built both on Smeaton's and Rennie's systems, but had not

obtained from them more than fifty-six per cent. of power; the velocity was generally about six feet per second.

Mr. Scott Russell had rarely seen better designed, or more ably executed machines than these ventilated water-wheels, and he thought the profession was under obligation to Mr. Fairbairn for the improvement he had introduced. He might instance, especially, one point of importance; this was the method of taking off the power, by inside gearing, from the loaded part of the periphery, thus avoiding all risk of straining the wrought-iron tension arms. Attempts had been made to improve upon the system, by taking off the power from the two sides of the wheel; but they had not been successful, as the gearing on both sides did not work well together, and a tremulous motion was communicated, which was very objectionable for spinning mills, where it was important to obtain the utmost regularity of movement. He had heard it remarked, that the yarn spun by water power obtained a higher price in the market, than that produced by steam power.

Mr. Russell had tried some experiments on water-wheels, and found the radial breast-wheels give very good results, with a fall of about fourteen feet, and the sluice and watercourse so arranged as to bring the water on with as little velocity as possible, filling the buckets properly, which, however, could only be accomplished up to a certain speed, without a system of ventilation. In high falls this became even more essential, and, in fact, indispensable.

Mr. Fairbairn explained, that he had tried both methods of taking off the power, and preferred taking it from one side only, as, in addition to the other objections, when the gearing was fixed on both sides, the elasticity of the wrought iron tension arms tended to break the teeth of the pinions. It could therefore only be done when the wheel was perfectly rigid.

Mr. Strutt, of Derby, and the late Mr. Hewes, of Manchester, had made many important improvements in water-wheels, particularly those on the suspension principle, which appeared now to be acknowledged as the most advantageous construction.

Mr. De Bergue said, he had obtained nearly seventy-eight per cent. of power, from a breast wheel, with a good fall, when the periphery was travelling at a velocity of six feet per second.

He had erected several of Poncelet's wheels, and thought well of them, indeed for certain situations he thought they were preferable to any other form, although M. Poncelet had never yet been able to obtain very superior results from wheels erected under his own superintendence.

Mr. De Bergue then exhibited a drawing (Fig. 4,) and explained

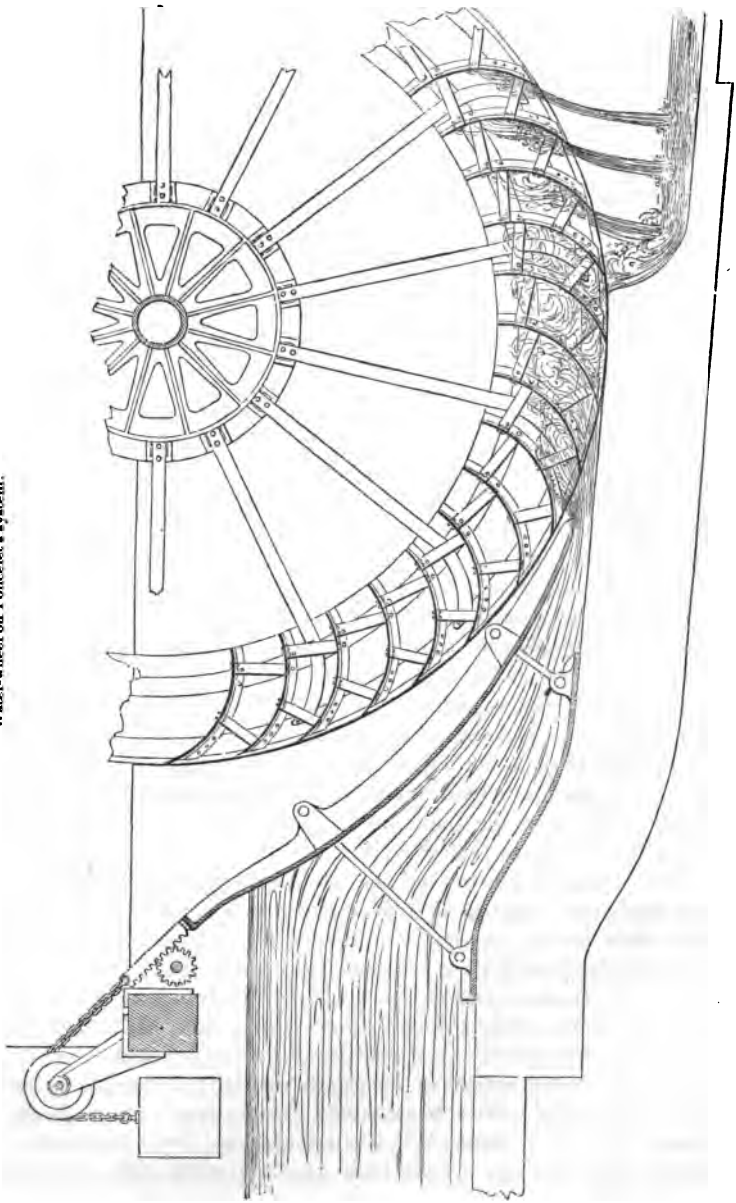

Fig. 4.
Water-wheel on Poncelet's system.

the construction of a wheel on this principle to be erected at the Loubregat, near Montserrat, in Catalonia; one of the same kind having been already erected by him at Gerona, between Barcelona and Bellegarde.

The diameter was sixteen feet eight inches, and the width was thirty feet, which with a fall of six feet six inches, passed one hundred and twenty thousand cubic feet of water per minute, when the periphery travelled at a velocity of eleven to twelve feet per second. An ordinary breast-wheel would require to be ninety feet wide, to use advantageously that quantity of water. It was found, that the velocity of the periphery should be about fifty-five per cent. of that of the water flowing through the sluice, and upon these data the power of the wheel would be about one hundred and eighty H.P.

The buckets were of a curved form, and made of wrought iron, one-eighth of an inch thick, and it would be observed, that there was a larger number of buckets than usual, and that the water came upon them at a tangent, through an orifice of such a form and dimensions, as to allow the buckets to fill easily, at the rapid speed at which the periphery passed before the sluice. This great primary velocity was very important, as it caused a considerable saving in the gearing of the mill.

The main shaft was formed by a hollow cylinder of cast iron, four feet six inches in diameter, in short lengths, bolted together, and the arms were of wrought iron, made very light, and of the same form as those of the paddle-wheel of a steamer, and placed very close together. The strain was brought entirely upon the main shaft, and the weight of the wheel was thus reduced to about thirty tons, which was very little for so powerful a machine.

The sluice was formed of cast-iron plates, with planed joints, bolted through the flanches, to form one large shuttle, of the entire breadth of the wheel, and its motion was regulated by radial tie rods, between the stone apron and the back of the sluice, which could thus be raised with great facility by racks and pinions, and be regulated by the ordinary governor, the weight of the sluice being in a great degree supported by the water flowing beneath it, on to the wheel. It moved very accurately between the side walls of the pen-trough, and cup-leathers at each side prevented any waste of water.

This kind of wheel was less affected by back water, than any other form, and the water acted upon it with its full power of velocity, without any impediment from the air in entering, as there was no sole-plate; the buckets were, therefore, filled and emptied with great facility.

Mr. De Bergue was satisfied, that this was the best kind of wheel for all falls under eight feet in height, and though the principle differed essentially from that generally taken as the basis of construction of water-wheels, he was inclined to prefer it to any other system.

February 6, 1849.

JOSHUA FIELD, President, in the Chair.

No. 795.—"Description of the Abattoirs of Paris."—By Richard Boxall Grantham, M. Inst. C. E.*

AMONGST the various measures which must be speedily adopted for the sanitary improvement of large towns, one of the most important is that of public slaughter-houses; it therefore becomes necessary, that their construction and management should be carefully studied; but as so few attempts have hitherto been made to introduce them into this country, at least with any degree of arrangement, examples must be sought for on the Continent, where they are almost universally adopted.

The abattoirs of Paris are perhaps, on the whole, the best specimens of establishments of this class, and their administration and statistics present some very remarkable features which deserve examination, previous to commencing similar constructions in Great Britain.

The butcher's trade in Paris is conducted on a peculiar system, and, like almost every other business, is under the control, or surveillance of the police, or the Municipal authorities; indeed, the extent to which this is carried, would here be deemed a great interference with the liberty of the subject, and would not be tolerated. Apart from this, there are many excellent regulations, which, whilst they prevent the unpleasant operations of that trade from becoming a nuisance, or being prejudicial to the health of the public, facilitate the computation of the fluctuations in the prices of food, enabling the masses to be provided for with certainty, and furnishing data for most interesting and instructive returns for the statist. At the same time they afford the means of controlling a class of men, who, from the very nature of their occupations, have become strangers to all the finer feelings. The abattoirs are prominent parts of this system, and it is conceived, that under a modified

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* The discussion on this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

form of administration, they may be rendered perfectly applicable to this country.

In contemplating these vast establishments, the first impression must be that of wonder at the comprehensive mind of the man, who, amidst the turmoil of war, the establishing, or overthrowing of governments, or meditating the invasion of distant kingdoms, and, in fact, whilst engaged in contention with half the world, was yet so intimately acquainted with the details of the internal administration of the country, and particularly with those of so important a question as the supply of food for the Metropolis, as to be able to devise and carry into execution a remedy for admitted evils. Perhaps nothing exhibits more clearly the soundness of the Emperor's views, and his admirable foresight, than the general completeness of the whole system, which has scarcely been changed since its first adoption; whilst, on the other hand, it is humiliating to our national *amour propre* to acknowledge, that Great Britain, in spite of its boasted cleanliness, still obstinately retains, in the centre of the Metropolis, and in the midst of a crowded and increasing population, that monstrous nuisance, Smithfield Market, surrounded by numerous slaughter-houses, with the other offensive trades incidental to them; and this, in defiance of the demands for a remedy, which can be so readily and cheaply supplied.

In 1810 the consideration of the entire question was submitted to a commission,* of which the Vice-President of the Council of Public Buildings was President, and combined with him was the Secretary of the same council, and M. Courbault, who had formerly been a butcher. This commission determined on a programme, which was made in that session, (October 14th, 1810,) and after the members had examined the proposals of five architects, they adopted a general plan for all the abattoirs, which shows the great pains and foresight with which the question had been considered, and demonstrates great knowledge of the necessities of the trade they were intended to assist.

A report was presented to the Emperor Napoleon, upon the evils which existed in Paris, from the slaughter-houses being situated in all parts of the city. The evils complained of were the filthy state of the streets, by the passing of the cattle through them, as well as the danger to the passengers; the putrefaction of the offal and blood lying about in the slaughter-houses, and which, being thrown into the River Seine, the great receptacle for it, spread disease and death amongst the inhabitants; the impossibility

* *Vide* "Almanach du Commerce de la Boucherie de Paris."

of preventing the sale and consumption of unwholesome and tainted meat, on account of the want of concentration, for the purposes of supervision; and the difficulty which existed of controlling those who conducted the trade of the slaughterer.

Upon this report a decree was passed, directing the erection of five abattoirs; three on the north side of the River Seine, and two on the south side, and on the 15th of September, 1818, they were opened for business. These establishments are very spacious, and there is no doubt but that still greater numbers of cattle might be slaughtered there than at present.

They are each respectively situated about one mile and three-quarters from the centre of the city, within the barriers, in spaces still tolerably clear from habitations; but probably at the time they were built, there were still fewer houses in their vicinity.

The following table gives their names, sizes, and the number of slaughter-houses in each:—

NAME.	Extent, in Acres.	Number of Sheds and Slaughter-houses.	Area of Slaughter-houses, in Square Yards.
Montmartre	8¾	64	3,872
Ménilmontant	10¼	64	3,872
Grenelle	7¾	48	2,904
Du Roule	5¾	32	1,936
Villejuif	5½	32	1,936

It should be stated, that the trade of the butcher is protected and regulated by a syndicate, or guild, which was established many years ago, and is formed of a President and six Associates. This body advises the Minister of the Interior upon all matters connected with the interests of the trade, both as respects the abattoirs and the markets, and is consulted upon the enactment of all laws tending to regulate it. It has also the command of certain funds, derived from the abattoirs, from which it grants superannuation pensions.

The markets from which Paris is supplied with cattle, sheep, and calves, are at Poissy, which is thirteen miles to the north-west, and at Sceaux, which is five miles and a quarter on the south of the city. There are two other markets in Paris for cows and calves, namely, La Chapelle and des Bernardins. The two former are of the most importance, and are under the control of the municipal authorities.

The market at Poissy is held every Thursday, and at Sceaux every Monday, when the butchers attend and purchase their stock.

At the former is established a branch of the Municipal Bank, at which the butchers have a credit according to a fixed regulation. Every butcher must be licensed to carry on his trade, and must give security, by depositing 3,000 francs (£120) in the Municipal Bank, up to which amount he can draw upon the Bank of Poissy, for payment to the sellers of the cattle which he purchases, and in some cases, according to his respectability and credit, he is permitted to exceed this amount, by paying interest, and repaying the loan and the original deposit within a limited time.

From the markets of Poissy and Sceaux, the cattle and sheep are driven to the abattoirs, by drovers who are under the control and license of the municipality, but who can only take a certain number, at one time, under their charge. They are responsible for any damage that may occur, and are also obliged to drive the cattle by certain routes, to the particular abattoir to which the cattle are consigned. The routes from each market to the different abattoirs are clearly laid down by the authorities in their code of regulations, and are generally along the roads encircling Paris, entering by the barrier nearest to the particular abattoir. Having arrived, the cattle are driven into pens, whence the owners select them, and drive them to their stalls, where they are kept till they are required to be slaughtered.

In Plate 4, are shown the plan, elevations, and sections, of the abattoir of Montmartre, which is the most important in extent. As before stated, they all so nearly resemble each other, that an explanation of one of them will suffice to render clear the construction and general arrangement of all. The entire space is surrounded by a high wall, so that nothing of what is passing within can be seen from the exterior, and the entrances are closed by iron gates, the avenues, passages, and yards being all paved, and provided with proper water channels and gratings, so as effectually to take off all rain-water drainage.

The slaughter-houses, A, are built of limestone, the walls being of plain rubble, with ashlar-dressed quoins, jambs, string courses, lintels, and plinths; the walls are about 16 feet high, and upon them is placed the roof, which is supported on timber posts. The roof consists of timber-framed principals, projecting a distance of 10 feet all round, open at the sides, and covered with pan-tiling of a heavy description.

Each slaughter-house is 16½ feet wide, by 33 feet long, and 15 feet high, and is fitted with a strong framework of timber, about 8 feet above the ground, consisting of two parallel beams, in the direction of the length of the building, and about 6 feet apart; they

are fastened into the wall at one end, but the other rests on another beam, which crosses the slaughter-house transversely. They are all provided with basins, hewn out of the stone floor, for collecting the blood, and large holding-rings are fastened into the floor. A small windlass is attached to the wall, so that in killing an ox, his head is brought down by a rope to a ring, and is held steady by one man, while another strikes it with a poll-axe; the carcase is then hauled up by the hind legs, and in that position is skinned and dressed, and it remains suspended till it is taken away by the butcher to his stall; about eight, or ten carcases can thus be suspended at the same time. At the sides of the walls and on the beams, are hooks upon which sheep and calves are hung, but in such a manner as to prevent their touching the walls. Each slaughter-house is well provided with water, so that after the dressing of each beast, the place may be thoroughly washed, and in order to prevent the blood from remaining between the flags, the joints are set with iron cement, level with the flagging. The slaughter-houses have two doors, one opening into an avenue, or passage, and the other into a yard, C, which generally divides one tier of buildings from another parallel to it, or to a building containing the stalls.

In this yard are the large benches on which the sheep and calves are killed; and down the centre of it is a channel, towards which the pavement inclines, like that of the slaughter-houses, leading to a grating over a sewer, where there is a proper trap to prevent the effluvium from returning.

The hides and skins are collected and taken away by the fellmongers; the intestines are also collected, washed, and sold. The tripe of bullocks, sheep, and calves, and the feet and heads of the two latter, are cleaned in an establishment fitted up for that purpose on the premises. The blood, of which it is ascertained that an ox contains three gallons, a sheep three pints, and a calf about a gallon, is all collected, and the cellular tissue and clot being separated from the serum, the latter is put into casks for use in the sugar refineries, where, however, it is not employed to the same extent as formerly, calcined bones being now more commonly used. The clot is subjected to a chemical process, by which it becomes nearly black, and is then put into casks and sold as manure. The contents of the paunches, which measure about two gallons each, are collected in the 'voiries,' or manure yards, and are taken away every day for manure, with the dung from the stables. The hearts, livers, and heads are taken by the butchers, and sold at their shops. The fat from the insides of the animals is collected and taken to the tallow-melting house, which is also on the premises.

Over each slaughter-house is a floor paved with hexagonal tiles, having a passage upon each side, the other part being divided off by a kind of wire netting. These were originally built for drying hides and skins, or for keeping meat cool until it was required to be transmitted to the butchers' shops. For these purposes this floor was admirably adapted, in consequence of the great projection of the roof, which keeps away the sun, and its being open to the tiling; but of late years these lofts have not been used for either of the above purposes.

The buildings containing the stalls, B, generally placed parallel to the slaughter-houses, or at their ends, are nearly similar in external appearance to those for the slaughter-houses, except that the roofs do not project so much, and the walls are carried up to the roof. The interior of them is, however, very different; they have a passage up the centre, and on one side the stall, or division for cattle, which, being about 16 feet wide, will each hold five beasts; on the opposite side of the passage are pens, which will each contain about twenty sheep and calves. The whole is lighted by windows, and has a door at each end, and sometimes one in the centre. Over each stall is a loft, reached by a staircase, divided off in the same manner as the stalls beneath. In these compartments each butcher, holding a stall, keeps his hay and straw locked up. The roof presents no particular feature worth recording.

There is also another kind of building, F, in which the fat is manufactured into tallow. The ground floor is generally occupied by the boilers, which hold from 1,000 lbs. to 4,000 lbs. each, in which the fat is melted. After it has boiled a sufficient time over a slow fire, the tallow is run off into tubs, and is left to cool; the residuum, or cellular tissue, is then put into a powerful press, and the remaining tallow forced out, leaving a cake of greaves, which is used as food for dogs and pigs. Under these buildings are cellars, in which the tallow is kept till it is required for the market.

The buildings marked I in the plan, are the 'triperies,' in which the tripes are cleaned and prepared, and the sheep's feet and calves' heads dressed for the markets. These are fitted with boilers and washing-places, but have no upper story, so that the effluvia from the process may ascend and pass through the tiling.

There are suitable buildings, G, for stables and coach-houses, and other conveniences.

The water is supplied, by different means, to each abattoir. At Montmartre it is pumped up into a reservoir, H, by a steam-engine. At Grenelle the celebrated artesian well affords an ample quantity,

but the water being naturally warm, it is allowed to cool before it is used. At Villejuif the water is pumped up by horse power. The two other abattoirs are supplied by a water company.

On each side of the entrance gates are the lodges, D, in which the superintendents and police reside, and where the office of the administration is kept. At the commencement of 1847, a new system of collecting the dues of the abattoirs was introduced, by which, instead of charging so much per head for the cattle upon entering, and weighing the tallow, all the meat which leaves the abattoirs is now weighed and a uniform rate of toll is charged; toll-houses have thus become necessary, and one is therefore erected in each abattoir, opposite to the entrance, having a weighing machine attached to it.

The returns of the annual expenditure and income of these establishments, prove that, as well as being highly important in the internal economy of the metropolis of France, they are profitable in a commercial point of view.

It is essential to impress these facts very strongly, because, great as the cost of their erection in this country must be, any doubts as to their becoming profitable investments will be removed, and thus one great objection to their introduction be obviated.

The population of Paris is about a million, and the following table * gives the number of cattle which have been slaughtered during the last four years at all the abattoirs:—

——	1844	1845	1846	1847
Oxen . . . . Head	76,565	77,543	80,256	82,519
Cows . . . . ,,	16,450	20,954	21,980	24,990
Calves. . . . ,,	78,744	83,282	84,444	83,577
Sheep . . . . ,,	439,950	59,470	487,644	503,113
Pigs and Wild Boars ,,	87,987	96,880	93,501	..
Tallow melted in the abattoirs . . lbs.	..	..	11,085,963	11,867,567

The original cost of the five abattoirs was about £680,000, including the purchase of land and every contingency; but there is no account of the cost of each.

The following is a general statement of the income and expenditure of all the abattoirs in 1846:†—

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* *Vide* "Annuaire du Bureau des Longitudes," page 118.

† From the "Compte Général des Recettes et Dépenses de Paris," Sheet No. 11, and page 92, Paris, 1846.

INCOME.

	£.	s.	d.
Tolls arising from slaughtering cattle, &c.	39,286	13	0
,, ,, melting tallow	2,062	5	0
,, ,, washing and dressing tripes, &c. .	6,046	18	0
,, ,, rent of slaughter-houses	213	0	0
	47,608	16	0
To which must be added the revenue derived from the sale, by public auction, of blood, manure, and sewage, as these belong to the syndicate* . . .	1,203	0	0
Total of Income	£48,811	16	0

EXPENDITURE.

Expense of the agents and labour for the abattoirs .	2,117	15	0
Expense of materials for the service of the abattoirs .	1,826	17	0
Restitution of undue and over-payments	200	0	0
Repair of slaughter-houses, stalls, stables, and other works	814	0	0
	4,958	12	0
To which must be added the payments of the syndicate for salaries of inspectors, petty expenses, charity, pensions, &c.*	1,203	0	0
Total Expenditure	£6,161	12	0

SUMMARY.

Revenue of all the abattoirs	48,811	16	0
Expenditure	6,161	12	0
	£42,650	4	0

The following are the receipts at all the abattoirs for the three years up to and including 1846:—

	£.	s.	d.
1844	44,077	14	0
1845	46,822	19	0
1846	47,608	16	0

The Author was induced to undertake this inquiry, with a view to the general introduction of abattoirs into this country, as a branch of the sanitary system, and he has also endeavoured to discuss the question of their applicability as a commercial undertaking.

He has here given such a selection from the information current

* From the "Almanach du Commerce de la Boucherie," 1846.

on this subject as he conceives to be most interesting and consistent with the objects of the Institution.

The Paper is illustrated by an engraving of the Abattoir Montmartre, impressions of which, (Plate 4,) are permitted to be taken for the use of the Minutes of Proceedings, and by four drawings, (Nos. 4,399 to 4,404.)

Mr. CHADWICK said he had listened to the Paper with great satisfaction, as it was connected with a subject to which he had devoted his most anxious attention. The evils of this kind which Napoleon removed in Paris, still remained in great force in London, and he feared it would need a power as absolute as that of the Emperor to eradicate them.

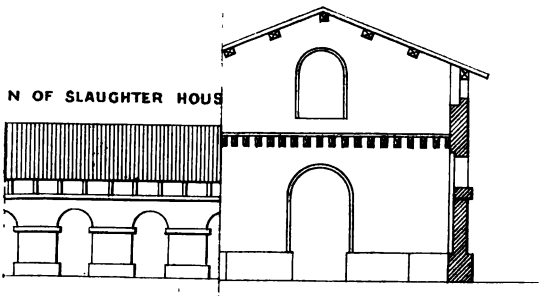
The subject had attracted the attention of Mr. Chadwick's colleagues on the Sanitary Commission, and its consideration had only been postponed, on account of other, though not more important inquiries. The chief difficulty, both in the Metropolis, and in other parts of England, was, he believed, rather administrative, than arising from a want of perception of the great convenience which abattoirs would offer in avoiding dirt and filth, disturbance in the streets, scenes of brutality, and the existence of a number of ill-conditioned places where the present system was perpetuated. The great evil, however, connected with the actual existence of slaughter-houses in the interior of towns, was that arising from the various offensive trades, such as tallow-melting, cat-gut making, &c, which were necessarily established in the immediate vicinity, and which eventually became more objectionable than the slaughter-houses themselves. One of the most important effects to be anticipated from the removal of the slaughter-houses, would evidently be the transfer of all the trades connected with them to some less densely populated neighbourhoods.

The objection of the butchers in England, (who, as a body, were not so united as in France,) to such an establishment as that at Islington was, that they were only exchanging the control of one irresponsible body for another, namely, from the Corporation of the City to a Joint-Stock Company. Now the real danger to the public, might be in trusting the butchers themselves with too much power; but that objection could be removed by legislative enactments, and an adaptation of the foreign system to the English trade, which would no doubt take place.

It had been expected, that the railways would bring a large quantity of killed meat to the London market; hitherto, however,

PLAN, ELEVATIONS

TRANSVERSE SECTION
OF SHEDS.



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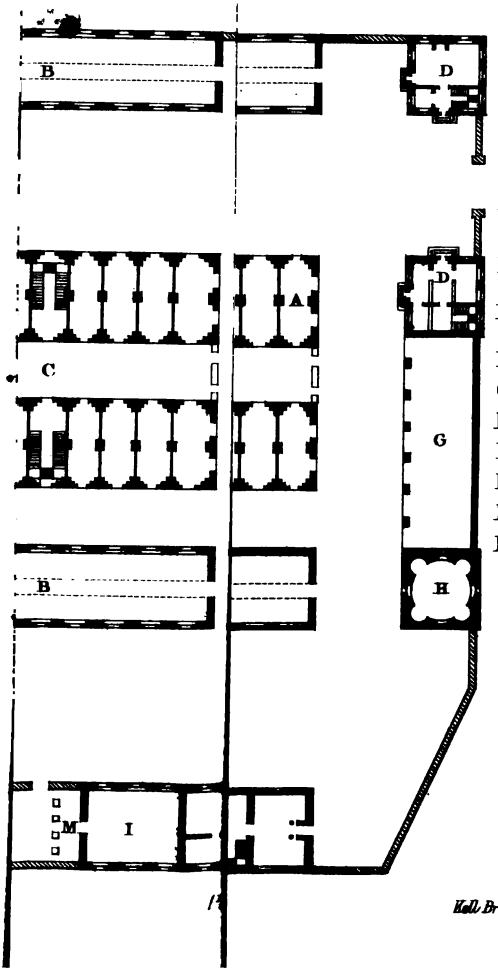

REFERENCE.

A. Slaughter House
B. Sheds
C. Yards
D. Porter's Lodge
E. {Residence of Superintendent
F. Melting Houses
G. Stables
H. Reservoir
I. Tripe Houses
K. Pens
L. Manure Yard
M. Privies

Hall Bro.s lith.rs Castle St. Holborn.

that anticipation had not been realized, and it had been stated, that the meat did not travel well, in consequence of inadequate accommodation for its carriage; but such a reason could not be permitted long to interfere, as the ingenuity of the carriage-builder would soon remedy that defect.

He thought Mr. Grantham had done well to bring the general question before the Institution, and he hoped that good would result from its discussion.

Professor OWEN had great pleasure in offering his testimony to the accuracy of Mr. Grantham's account, as on more than one occasion he had carefully examined the question, particularly in the autumn of 1847, when as a member of the Metropolitan Sanitary Commission he inspected the abattoirs, and their dependencies in Paris, with great minuteness, receiving every possible facility from the authorities, and being much assisted in his inquiries by the admirable documents published annually by the Préfet de Police, and the Syndicat des Bouchers. The great feature which called for admiration in the abattoirs of Paris, was their bearing, in an economical point of view, on all the numerous classes who were affected by the supply of animal food; the graziers were benefited by extensive markets being provided for them, where their cattle were easily examined, and where the trade was enabled to go on directly between the grazier and the actual purchaser, without the system of middlemen, or meat salesmen, whose assistance became indispensable in London, on account of the difficulties of Smithfield. This was one of the direct taxes on meat, which the consumer had to pay.

A more important benefit was the arrangement of the markets, which rendered it almost impossible, that any diseased meat could enter Paris. By the excellent existing supervision, every tainted, or diseased animal was at once rejected, and its introduction entailed due punishment. Then, after the grazier, the master butcher derived a benefit, by receiving the cattle in the best-possible condition for killing, as they were not over-driven, the abattoirs being so placed and the system of conveying the fattened beasts to them being so arranged, that they came there in a totally different state from that in which they arrived at Smithfield. The contrast was extremely striking, and as a physiologist he conceived it to be of the greatest importance to the wholesomeness of the food.

In London the majority of the beasts were slaughtered in a state of fever, and when the blood was in an unnatural state. The microscope clearly demonstrated the shocking state of the animals, and it was a fact that he had never met with the blood of a calf, ox, or

sheep in a slaughter-house in his own neighbourhood, (Clare Market,) which he could pronounce to be in a thoroughly healthy state, and it followed of necessity that the quality of the meat was deteriorated.

There were a few first-rate wealthy butchers in London, who avoided this evil, by having their own fields, or turning their sheep into the Parks for a few days; but in Paris it was entirely obviated, by placing the abattoirs at the extremities of the city, although within the walls, on account of the municipal duties. It would be difficult to improve the internal arrangements of the Paris abattoirs, but if they were susceptible of amelioration, he was sure the suggestions would emanate from the Members of the Institution of Civil Engineers. At the abattoirs in Paris, the sheep were placed in small paddocks, the cattle had plenty of straw, and in some places grass yards, where they rested for some days, and were therefore in a perfectly healthy state when they were slaughtered; for it was of little real avail having the cattle apparently free from disease, if they were driven into a fever before they were killed, which was the case with nearly all the cattle brought into the Metropolis. In Paris too, there was no waste of the offal, all the parts of the animal being systematically converted into their immediate profitable use. Now that the blood was not entirely used for purifying sugar, the French adopted a chemical process, for converting it into a solid manure, which appeared to be equal to guano; and all those operations were carried on without that extent of injury and inconvenience to the neighbourhood which appeared inseparable from the system of this country.

Another advantage was, that the butcher, getting his meat in a better condition, was able to keep it fresh much longer than it could generally be kept in London, for he had seen in Clare Market, fine joints of meat thrown on to the offal heap and carted away, in thirty hours after the slaughter of the animal: this had been the case with carcases which had been suspended for only one night in the tainted atmosphere of the slaughter-house. The owners of these places appeared not to know, that a piece of fresh meat, placed within the atmosphere of tainted meat, would rapidly partake of the corruption, and seemed also not to be aware, that their filth and ignorance combined to make them pay a large fine out of their own pockets, in the shape of meat thrown away, if it could not be forced, by its cheapness, on the poor inhabitants of the district.

He wished, if the Parisian system was introduced into London, that its benefits should be enjoyed by all; but he feared, without due legislative control, that the benefit of it would be obtained only

by the spirited individuals who got up, on private grounds, the first movement in the right direction; it was right they should be rewarded, but he thought it was better that the movement should be so directed, as to insure a benefit to all classes. It was a fallacy to suppose, that Englishmen would not endure the restrictions, to which the butchers were subjected in Paris; there were other classes of men equally sensitive, and possessing the true spirit of Englishmen, who had for years, (until lately,) endured a more galling interference,—the supervision of the glass-makers, the distillers, and other trades, by the Excise. He had no doubt, that Englishmen would submit to such regulations as a wise Legislature deemed proper for the benefit of all, particularly when they did away with the evil and nuisance of such a place as Smithfield.

Mr. LESLIE conceived, that the passage of the cattle through London to the Islington market would still be a great nuisance; he had been told that a large number of the sheep which came to London, arrived from Kent, and the nuisance of their going through London to Islington, would be greater than that caused by their going to Smithfield. He also called attention to the fact, that the £42,652 paid over to the city of Paris was not clear profit, but was a return of about 6¼ per cent. on the original cost of the abattoirs.

Mr. C. MAY conceived the subject was so clear to the common sense of every one, that it resolved itself simply into a pecuniary question, affecting the City of London, and when that was arranged, the whole matter would be settled. Bad as our system might be, he still thought better beef was to be had in London than in Paris: but he believed great improvements might be introduced, and that the best mode of carrying out their views would be, by impressing them on the public mind, and by showing the butchers the losses they sustained, in every way, by the present system.

Mr. ARMSTRONG begged to direct the attention of the meeting more directly to the Islington market, with which he was intimately connected, and of which the actual circumstances should be correctly known.

An Act of Parliament was in existence, for establishing that market, and allowing certain limited rates of tolls to be levied; it was only proposed to establish one abattoir at that spot, and there was no idea of monopolizing the whole trade of London, which indeed would be impossible. This was proved at Paris, where, in a city so much smaller, it was found necessary to have five abattoirs; it therefore did not require much argument to show, that a larger number of establishments would be required for London, and those

should be so placed, as to intercept all the droves of animals arriving in the Metropolis. It was proposed, at the Islington market, to attach to the abattoir small sheds, to be let, at a certain rent, to the butchers, where their own servants might kill the animals. If by any mutually advantageous arrangement, the Company could take from the butcher those parts of the offal, &c., which were used for various manufactures, the public would rather be gainers.

When other abattoirs were established, it would be competent for a butcher to select that one which afforded him the greatest accommodation, and if the Islington Company should demand too high a rent for their shops, competition would spring up, and thus the matter would speedily find its level. Seven-eighths of the cattle arriving in Smithfield came from the northern counties, and were mostly carried by railway; and even with regard to the sheep from Kent, they might be ferried across the river, and brought by the West India Dock Junction Railway, which now came within less than four hundred yards of the Islington market, into which there would soon be a branch formed; or by the railway bridge constructed across the river at Richmond, by which means, the passage of cattle, through the streets of London, would be entirely avoided.

Mr. ALLEN RANSOME said he was intimately acquainted with the views of the farmers on the subject, as he had heard the question discussed at their club. The unanimous feeling appeared to be, that an establishment outside the Metropolis, with adequate room for the animals, where they could be free from that state of excitement to which they were subjected, from being driven through the streets, would necessarily be advantageous; the main thing that opposed itself to the plan, was the actual scarcity of buyers there, and he much feared that as long as the interests, which then surrounded Smithfield market, were made to tell, as they now did, on the butchers and salesmen, so long buyers would be deficient there; he thought the best way to remove that objection, was to get up a feeling of willingness in the minds of the farmers, to trust their stock in a better place, and he had no doubt, that purchasers would then go to a place where the cattle could arrive without the loss, or damage, to which they were now subjected. The salesmen were the parties who really interfered most, to prevent this desirable improvement for the farmers and the public, and they were actuated solely by the principle of self-preservation, because from the moment that the butchers could easily come into actual contact with the farmers, and purchase directly from them, the occupation of the salesman would be gone. It must be self-evident, how desirable it

would be to do away with the present system, and there could not exist any reasonable doubt of the proposed improved measure being soon fully carried out.

Mr. C. FOWLER said, his experience in markets convinced him of the great evils attending the mode in which beasts were now slaughtered, and of the degrading tendency of the proximity of such places. On visiting a slaughter-house, he had been surprised to find young tradesmen in the neighbourhood attending and officiating as amateur slaughterers. He was happy to see the present movement, which, however, he thought had been taken up with more spirit in the provincial towns than in London.

A very interesting report had been published by a Commission from the late French Government, which had visited London, as well as most of the principal cities of Europe, in order to collect information on this subject. In that report, the Commissioners commented somewhat severely, but courteously, upon the actual state of the butchers' trade in London, and made many interesting remarks upon the subject.

The great opposition to any alteration in the present system, was the vested interest of those supporting it, because they were in turn supported by the system. These vested interests should be met by some strong measure of the authorities, and if the public expected to be benefited, they must adopt strong measures, to impress upon the Legislature, the necessity for the consideration of these crying evils, and of the adoption of some mode of remedying them.

Mr. ELLIOTT thought it right to mention some objections urged by the trade against the general establishment of abattoirs in this country; these were, that it would be necessary to send their servants to the abattoirs to slaughter the cattle, and they might possibly be at some distance from their shops; that they might collect there in numbers and form bad habits; and also that the butchers would not have so well-regulated a supply of meat as at present. If the supply was now deficient, they had but to send to their slaughter-house, and kill one, or two sheep, to meet the wants of their customer; whereas under the proposed system it might be necessary to send several miles for the purpose.

There could be no doubt of these objections being eventually overcome, but they must at once be met in the proposed arrangements of any establishment, for it was essential to receive the co-operation of the butchers, which could only be obtained by meeting their views liberally.

Professor OWEN explained, that no persons were permitted to congregate in, or about the abattoirs of Paris, excepting those who

were actually employed there, and that the internal arrangements were so excellent, that no bad conduct would be tolerated. In Paris, in addition to the general cleanliness observed in the shop, and the rapid removal of the offal, the butcher brought to his shop in the abattoir vans, excellently constructed for the purpose, only the meat which was required to be sold within a given time, whereas in London the whole live beast was brought home, although only two-thirds of it was available for food; the hides lay about, and were irregularly taken away, and the blood was collected in the 'blood-hole,' which was not regularly emptied, nor was the other offal and dung conveyed away quickly enough. All these combined to render the present system seriously prejudicial, not only to the sanitary condition of the immediate neighbourhood, but to the whole Metropolis.

It was remarkable that in England, where the advantages of the introduction of machinery and tools were so fully appreciated, such a stubborn adherence should be shown, to an antiquated and vicious course with respect to their markets, and such a want of perception of economy. By the present system, the drover was actually paid for depreciating the value of the animals, by his treatment of them, and it was deemed preferable to pay for the risk of an accident in the crowded streets, than to send the beasts for sale to a convenient spot in the suburbs. This was blindness enough, but it was difficult to imagine how, or why, the public would continue to submit to the annoyance, danger, and inconvenience to the traffic, as well as to the filth in the streets, caused by the passage of these droves of animals, when they had eventually to pay for it, in the shape of an increased price for meat, which really amounted to an enormous tax upon the public at large.

Mr. GRANTHAM stated that in a treatise he had written on the subject,* he had alluded to the propriety of all the manufactures connected with the use of the offal, being included in, or concentrated around, one establishment. The establishment of abattoirs, would also be of use, in ascertaining accurately the consumption of meat in London, which at present was not practicable. In Paris every butcher who killed meat paid a duty per pound on the meat leaving the abattoir: this he conceived to be a good system, as the butcher could lock up his meat in his store at the abattoir,

* *Vide* "A Treatise on Public Slaughter-Houses, considered in connection with the Sanitary Question; describing the practice of Slaughtering in France and England, with an Historical and Statistical Account of the Abattoirs of Paris." By R. B. Grantham. 8vo. London. 1848.

without its being under the control of the Company; there was also a strict police at the gates which prevented anything like theft. He had no doubt, that when abattoirs were established in the Metropolis, along with the different trades in connexion with them, the butchers would find that they could kill their meat more economically than at present, and instead of the expense being three shillings and sixpence a head for cattle, it would not be more than one shilling and sixpence.

He thought abattoirs were desirable in every point of view. The offal was disposed of with much more difficulty in the country than in London; but if central establishments like these were formed, there would be a certain sale for everything.

The contrast between the system of private killing of animals in London and the abattoirs of Paris, was not more striking than that between the markets of Smithfield and Poissy, and in neither case was it to the advantage of England.

Mr. C. MAY could not help remarking, that there would be great objections to including any of the offensive trades within the walls of an abattoir, as the tendency must evidently be, as had been stated by Professor Owen, to taint the meat, and thus do away with one of the great advantages of the proposed establishments, which he sincerely wished to see commenced immediately.

Mr. GRANTHAM said, with reference to the observation made by Mr. May, as to the evil of connecting offensive trades with the slaughter-houses, he thought the modes proposed in the pamphlet, which he had laid before the Institution, would quite meet that difficulty; the ventilating towers would carry off most of the offensive ingredients that would arise, in addition to which they would be well partitioned off, so that the draught could not carry any of the effluvia to where the meat was kept; and another important part of his plan had reference to the preservation of meat during the summer, in rooms properly ventilated and cooled by dry air and other artificial means.

February 13, 1849.

JOSHUA FIELD, President, in the Chair.

No. 788.—"The Coal-field and the Coal of South Wales."*—By Joshua Richardson, M. Inst. C.E., F.G.S.

A PLENTIFUL supply of good coal is essentially necessary to the national existence of this country; for without an abundance of this valuable mineral, its manufacturing industry and commercial enterprise would be paralysed, and cease to be the sources of that great wealth for which Great Britain is now distinguished amongst the nations. It also very materially contributes to bodily health and domestic comfort, as, next to food and clothing, fuel is, undoubtedly, one of the most indispensable necessaries of civilised life.

Thirty years ago, Sir Humphry Davy said:—"Science had made pit-coal an important instrument in the hands of the chemist and mechanic; it had made the elements of fire and water perform operations which formerly demanded human labour, and it had converted the productions of the earth into a thousand new forms of use and beauty." Since this was written, great progress has been made, in still further developing the utility and power of these elements, and in applying them not only to the saving of human, but of animal labour, which they have superseded, and in some instances, far surpassed, in celerity and effect. Fire and water have not only been employed to facilitate internal communication, but have also been made to enter successfully into competition with the wind, as a motive power on the ocean, and, by diminishing the time required for communicating with distant countries, have, in effect, brought them nearer to each other.

The progressive extension of this new power,—the consequent amazing increase in the consumption of iron and other metals, in the production of which coal is an indispensable agent,—the augmenting demand for other manufactures, and for export to other countries,—and the rapid increase of the population,—have all tended to augment the present consumption of coal so steadily and progressively, to an amount unprecedented at any former period, that serious apprehensions have been entertained of the exhaustion

* The discussion on this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

of the sources of supply, at no very remote period. These fears were chiefly excited in relation to the great northern coal-field, situated in the counties of Durham and Northumberland, from which London and great portions of the country on the east and south coasts of England and Scotland are principally supplied. Several estimates were made of the probable duration of the supply to be derived from this district, and it is curious to observe the great discrepancies which appear in the results of these calculations. In 1801, Mr. Bailey stated, that the supply would only last 200 years; in 1792, Dr. MacNab calculated it would be exhausted in 375 years; in 1830, Dr. Buckland estimated it would all be consumed in 400 years; in 1830, Professor Thomson thought it would serve at least 1,000 years; and, in 1830, Mr. Hugh Taylor proved there was coal enough for 1,727 years.

Apart, however, from these predictions, this valuable coal-field is, undoubtedly, annually approaching to a state of exhaustion. Nor is this a matter of surprise, when it is recollected, that the coal from this district has been extensively used, during upwards of six centuries, both for home consumption and for exportation; and although, in the early part of this period, the quantity was comparatively inconsiderable, yet of late years, owing to the establishment of iron and other large manufactories in the district, and an increasing demand for it elsewhere, the quantity shipped has, alone, been augmented upwards of 5,300,000 tons per annum since the year 1800.* There are no means of ascertaining the amount of the home demand, but there is no doubt that it, also, has recently very considerably increased.† The time must, therefore, come, and that at no very remote period, when the capability of the Newcastle district

	Tons.		Tons.		Tons.
* In 1847 shipped coastwise	5,921,037	over sea	1,806,638	Total	7,727,675
In 1800 ,, ,,	2,217,070	,,	135,438	,,	2,352,508
Increase . .	3,703,967	,,	1,671,200	,,	5,375,167

† This want has been since supplied by the publication of the "Mining Records," by Mr. Robert Hunt, F.R.S.; from which it appears, that in this district, 15,431,400 tons of coal were worked in the year 1855. This quantity was disposed of as follows:—

	Tons.
For home consumption	3,850,000
Shipped for London and the coast . .	8,567,028
Shipped for foreign countries . . .	3,014,372
	15,431,400

For an account of the quantity of coal raised in this and other districts in the year 1855, see the tabulated statement in the Appendix.—[J. R., Jan. 1858.]

to supply coal equal to the progressive demand for it, both at home and abroad, will become so limited, from the increased difficulty and additional expense in producing it, that other sources of supply must be resorted to, where coal is to be found in greater abundance, and where it may be procured at a cheaper rate. The extinction of the coal trade in the North will probably be gradual, and long precede the total exhaustion of the coal-field; for although the consequent increased cost of production may exclude it from the London and other distant markets, yet it may still, for a much longer period, prove more economical to use it in its own district, than to import from other places.

The certain and progressive exhaustion of coal is not confined to the Newcastle district. In Staffordshire, where the area of the coal-field is only rather more than one-half that of Northumberland and Durham, the immense consumption in the iron-furnaces and foundries renders it probable, that the extinction of the collieries in this district will precede that of the northern counties. The Derbyshire, Yorkshire, and Lancashire coal-fields are situated amidst numerous manufactories and great populations, and have a demand for home consumption quite equal to their means of supply.

It becomes, therefore, a subject of interesting inquiry to ascertain if there are any other sources of supply whence the present enormous and constantly-increasing demand for coal can be supplied, for the consumption of London and other places similarly circumstanced as to their geological position. If the importance of a subject is measured by its utility, there are few which have stronger claims on the attentive consideration of the Institution than this question, when it is viewed in all its bearings and consequences. In most, if not in all engineering operations, coal is an indispensable auxiliary, and on its goodness and cheapness much depends, both as to the stability of the work and the ultimate success of the project; nor can there be a greater hindrance to the internal improvement of a country, than an inadequate supply of inferior fuel.

In the event of such a dearth of coal occurring in England, as has been anticipated, and towards which there is, undoubtedly, a progressive and steady advance, it is fortunate, that there is a coal deposit in South Wales, from which an almost exhaustless supply may be obtained. The coal of this district is comparatively little known, save as a subject of geological interest, and its being extensively used in the production of iron, the smelting of copper, and the manufacture of tin plates. Its introduction into general consumption in London and other places has only been very partially effected; and its value, from many causes which will be afterwards

noticed, is not only imperfectly appreciated, but strong prejudices are entertained against it. Necessity will induce a more intimate acquaintance with it, and as the merits of this coal become more generally known, prejudices will subside, and it will assume that importance among the national productions, to which it is really entitled. In the meantime, it may be an interesting, if not an instructive inquiry, to ascertain the extent and quality of this coal, and whether it can be produced as cheaply as in other districts; for however plentiful the supply might be, the requirements would be but very imperfectly answered, if the coal was of a very inferior description, or more than ordinarily expensive. The localities and quantity of the coal in South Wales, therefore, will be first described, its various kinds and qualities will be then shown, and the cost of producing it will be subsequently stated.

The area of this coal-field has been variously estimated, by different authors, at from 100 square miles to 1,200 square miles. In order to ascertain which of these estimates approximated most nearly to the truth, the Author computed its area from the geological maps published by Mr. Knipe and by the Board of Ordnance, and found it to be 1,055 square miles; and that about two-thirds of it is of a bituminous quality, and one-third anthracite, or of a non-bituminous description. The dimensions were taken from the inside boundary of the Millstone Grit, or Farewell Rock, (as it is locally called,) or its equivalent; and the results from each map were very nearly coincident. The respective quantities of bituminous coal and anthracite were taken from Knipe's map only, and must be considered as approximate and not certain data, as the one description frequently merges into the quality of the other, so as to render a distinct line of geographical limit to each kind impossible; and it sometimes happens, that both bituminous and anthracitous coals are found in the same ground.

This coal-field commences on the east, in the county of Monmouth, and extends westward through Glamorganshire, Brecknockshire, and Carmarthenshire to the western boundary of the county of Pembroke. It is parallel with the Bristol Channel, the numerous harbours of which give every facility that is required for its export; and the railways which are now being constructed in the principality, will tend to lessen the expense of its carriage from the collieries to the shipping ports and markets for home consumption.

In Monmouth, the coal is found in the western part of the county, abutting on Glamorganshire in the south-west, and on Brecknockshire in the north. Its average length is about 7 miles, and its

breadth 15¼ miles. The whole area of the coal, which in this county is bituminous and 'free-burning,' is 110 square miles. It is extensively used in the smelting and manufacture of iron at the Tredegar and other large works on the northern boundary, and considerable quantities of it are shipped at Newport, which is about 6 miles distant from the nearest part of the coal-field, in a south-easterly direction.

Coal extends over four-fifths of the entire county of Glamorgan; it embraces every description, as well as every quality of coal found in South Wales, and covers an area of 546 square miles, of which 462 square miles are bituminous and free coal, and 84 square miles are anthracitous. Of the above quantity, 26 square miles are under the sea, in Swansea Bay. Both descriptions of this coal are extensively used in making iron, and large quantities of the bituminous quality are used in copper-smelting, and in the manufacture of tin plates, &c. Both kinds are exported, but not to the same extent as the coal in Monmouthshire.

There are only 78 square miles of coal in Brecknockshire, the whole area of which is shown by Mr. Knipe as anthracitous. It is principally situated on the south-west corner of the county, adjoining the counties of Glamorgan and Carmarthen. It is extensively used in the iron-works near Merthyr Tydvil, and large quantities of iron-stone are obtained from near the lower coal-measures.

In Carmarthenshire, there are 241 square miles, 105 of which are under the sea, in Carmarthen Bay. Of the whole quantity, 117 square miles are shown as bituminous and 124 square miles as anthracitous. It is used, like the former, in the smelting and manufacture of iron, and a considerable quantity of this coal is annually shipped at Llanelly. Argillaceous iron-stone of superior quality is also obtained from the inferior measures of this district.

The coal continues westward, through the whole length of Pembrokeshire, in a strip, narrowing as it proceeds to Bride's Bay, at the extremity of the county, where it continues its course along the bay, at right angles with its former direction. The whole area occupied by it, in this county, is only 80 square miles, and all of it is anthracite, some of which is of a very superior quality; it is exported to the agricultural counties to be used in stoves,—for drying hops, malt, &c.,—and for burning lime, for which purposes it is preferred to bituminous, or any other description of fuel.

The following Table exhibits a recapitulation of the areas in each county, and of the whole coal-field:—

	Bituminous.	Anthracitous.	Totals.
	Sq. Miles.	Sq. Miles.	Sq. Miles.
Monmouthshire . .	110	. .	110
Glamorganshire . .	462	84	546
Brecknockshire . .	. .	78	78
Carmarthenshire . .	117	124	241
Pembrokeshire. . .	. .	80	80
Totals . .	689	366	1,055

From various causes there is great difficulty in correctly ascertaining the average depth, or thickness of the coal, for although some of the veins, or seams, can be traced for a considerable distance, it yet remains to be proved, that any one vein of coal extends over the whole area. Even those veins which are indisputably recognised, in different localities, as being identical, vary so much in thickness, or are so interrupted by abrasions and gaps, produced by denudation, or other remote causes, as to preclude the possibility of making any true estimate of its thickness throughout the entire basin, or even over any great portion of it. It appears from sections published by the Rev. W. D. Conybeare, and from the Ordnance Survey, exhibiting the general disposition of the strata, in a line from north to south, across this coal-field, that there are two deposits of coal, which are separated from each other by a rock of considerable, but varying thickness, called the Pennant Grit. The coal of the upper series is not equal in quality to that of the lower; and it is in the lowest shales, that iron ore is found in the greatest abundance. The effects of denudation are clearly shown in these sections, particularly in the upper series; abrasions and gaps, where the coal has altogether disappeared, are occasionally to be observed. The lower series has suffered diminution from the same cause, and in some situations, the loss has been very great; and there is good reason to believe, that a great portion of the original deposit has long since been wasted away. This view of the subject is strikingly confirmed by the relative quantities of coal found in different places, as shown in the sections recently published by the Ordnance, and by others in the possession of the Author. For instance, in the section of the strata of the lower series, taken on the east crop, at Pontypool, (Monmouth,) there are only twenty-three veins, amounting in the aggregate to 42 feet of coal, whilst at the Plymouth iron-works, which are situate on the north crop, and about 15 miles north-west of Pontypool, there are thirty-three veins containing 50 feet of coal; and at Cefn Crebwr, which is on the south crop and about 28 miles south-west of Pontypool, there are only twenty-three

veins, of an aggregate thickness of 80 feet. These discrepancies occur in the lower series, in such situations as have exposed the veins to the effects of denudation, the results of which are by no means uniform. In the upper series, there is a still greater difference in the quantities of coal shown in the several sections taken at different, but not very distant places; and the area of these veins is so much cut up and divided by valleys, as to leave the coal only in strips and patches. That portion, therefore, of this coal-field in which all the veins are to be found, is of a very limited extent, and in estimating its quantity, very liberal deductions must be made from the dimensions of the original deposit. It would require great labour, as well as an intimate and exact knowledge of the coal-field, to estimate its contents truly and correctly; and in the absence of more satisfactory information, the following statement of the number and thickness of the veins of coal in the upper and lower series, is extracted from the "Memoirs of the Geological Survey of Great Britain," by Sir Henry De la Bèche.

	Under 2 Feet.		2 Feet.		3 Feet.		4 Feet.		5 Feet.		6 Feet.		7 Feet.		9 Feet.		10 Feet.		Totals.	
	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.	Veins.	Thickness.
	No.	Ft. in.	No.	F. in.	No.	F. in.	No	F. in.	No.	F. in.	No.	F. in.	No.	F. in.	No.	F. in.	No.	F. in	No.	Ft. in.
Upper Series	21	23·10	6	13 0	5	15·6	2	8·6	4	20·6	.	.	2	14·0	1	9·0	.	.	41	104·4
Lower Series*	7	7· 0	4	10·0	.	.	4	16·0	3	15·0	2	12·0	1	7·6	1	9·0	1	10·0	23	86·6
Totals .	28	30·10	10	23·0	5	15·6	6	24·6	7	35·6	2	12·0	3	21·6	2	18·0	1	10·0	64	190·10

It thus appears, that there are sixty-four veins, or seams of coal, the aggregate thickness of which is 190 feet, and the area of this coal-field, as before shown, is 1,055 square miles.†

The authority generally referred to, and most relied on, as to the extent of the South Wales coal-field, is a Paper by Mr. Martin,‡

* The lower series is said to contain 60 inches of argillaceous, and from 18 inches to 36 inches of carbonaceous iron ore, which are calculated to produce 11,000,000 tons of ore, per square mile.

† The Newcastle coal-field has been estimated by the Author at 840 square miles, and it is said to contain 12 feet of workable coal; 105 square miles of which were exhausted in the year 1826. The areas of the following coal-mining districts, are as follows:—

Great Britain and Ireland . .	7,995	square miles.
France	914	,,
Belgium	486	,,

‡ *Vide* Philosophical Transactions, vol. 96, p. 345.

in which the area is estimated at 1,000 square miles, and the thickness of the workable coal extending over the whole of this area, is said to be equal to 95 feet. Mr. Martin takes only half of the aggregate thickness, shown in the foregoing extracts from the Ordnance sections, yet for reasons before stated, it may be fairly doubted, whether his estimate does not exceed the probable average thickness of the coal throughout its whole area. In the absence of exact measurements of the existing extent of the several veins and their varied thicknesses, any precise estimate of this description must be viewed only as conjectural; there can, however, be no doubt, from the facts already stated, that the quantity of this valuable mineral in South Wales is immense, and that, in area and thickness, it far exceeds any other coal-field in Europe.

In connection with this subject, the present consumption ought to be considered, so as to show the rate at which the process of exhaustion is proceeding, and what relation it bears to the whole quantity, and to the consumption of other districts. A brief notice of the several sources of demand may be interesting, and serve to prove the great national importance of this coal-field in sustaining the vast manufactures of metals which are dependent on it.

The rapid and increasing growth of these establishments affords presumptive evidence of the value of this coal, and of its fitness to be more extensively introduced into general consumption. The largest quantity is used in the smelting and manufacture of iron, which was first introduced into this district about a century ago.* There are now one hundred and eighty-seven blast-furnaces in this district, of which one hundred and forty-eight are in blast. The quantity of iron annually made in South Wales, amounts to 840,000 tons.† The quantity of coal used in making this iron, and in manufacturing a large proportion of it into bar-iron, is estimated at

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* "The smelting of iron with charred pit-coal was first successfully effected, on a large scale, at Coalbrook Dale, (Shropshire,) about the year 1740. In 1755, Mr. Bacon obtained the lease for ninety years, of a district of country near Merthyr Tydvil, 8 miles in length and 4 miles in width, at the very low rent of £200 per annum. It is understood, that his right extended only to the iron and coal mines found on the estate, and that he had a very small portion of the soil, or surface, on which he erected works for the smelting and forging of iron. Soon afterwards, about the year 1783, he granted leases of his remaining term in the following parcels:—Cyfartha works, the largest portion to Mr. Crawshay, and the remainder to Mr. Hill."—"Malkin's Walk through South Wales," vol. i., p. 278.

† The quantity of iron made in Great Britain in 1846, was 1,750,000 tons, of which 500,000 tons were exported.

2,850,000 tons per annum; and the value of the iron smelted and manufactured with it, is stated to be £3,050,000 per annum.

Copper-smelting was first instituted in this district about the year 1690, in the neighbourhoods of Swansea and Neath, where it is still pursued on an increasing scale, and has been extended to Port Talbot on the east, and Llanelly on the west. In this district, 26,000 tons of copper are annually produced,* the ores being imported principally from Cornwall, Chili, Cuba, and Australia. These works consume 400,000 tons of coal annually, and the value of the copper thus produced is estimated at £2,600,000.

The manufacture of tin plates, (thin plates of iron tinned over,) appears to have first taken place in 1681, and the establishments of this district in which this simple and interesting process is carried on, are the most extensive in the world. When in full operation, they produce five hundred and twenty thousand boxes of tin plates per annum, but at present, the produce does not exceed three hundred and thirty-five thousand boxes. The tin annually used for this purpose, which amounts to 1,500 tons, is imported from Cornwall, and costs £135,000. The coal consumed in the process annually, amounts to 250,000 tons, and the value of the tin plates manufactured with it, is said to be £550,000.

A considerable quantity of coal is used in the spelter, chemical, patent-fuel and other manufacturing works in the district; also in the burning of lime, for building, agricultural and other purposes. It also serves for the domestic uses of a resident population of about six hundred thousand souls; and its abundance and consequent cheapness induce a much larger consumption in this district than is usual for such purposes. The annual consumption under this head has been safely estimated at 750,000 tons, and its value is about £180,000.

Although the export of coal from this district may appear inconsiderable, when compared with that of the Newcastle coal-field, and the relative means of supply, yet as its superior adaptation for many purposes becomes more generally known, the demand for it will, doubtless, greatly increase. From 1833 to 1847, the shipments have augmented upwards of 60 per cent., which may be viewed as an indication of the enhanced appreciation of its economical value. Its distance from London by water, being twice that of the northern coal-field, necessarily renders the cost there rather

* In the United Kingdom, the whole produce is 28,000 tons, of which 17,000 tons are exported.—Mr. Hunt estimates the quantity of pig-iron made in Great Britain, in 1855, at 3,218,000 tons.—[J. R., Jan. 1858.]

greater than that of the Newcastle coal; but as is afterwards shown, this increased price per ton is amply compensated for, by the more peculiar, durable, and other qualities of the fuel.

The following account of the shipments of coal, culm, and cinders from South Wales, in the year 1847, is extracted from the Parliamentary returns:—

	Coastwise.	Over sea.	Totals.
	Tons.	Tons.	Tons.
Newport	436,099	116,098	552,197
Cardiff	432,726	81,032	513,758
Swansea, Neath, &c.. .	373,307	46,715	420,022
Llanelly	204,391	14,178	218,569
Totals . . .	1,446,523	258,023	1,704,546

This quantity is considerably less than that shipped in the three years preceding, owing to the extraordinary depression of commerce and manufactures. Taking the average of 1844, 1845, 1846, and 1847, the exports are 1,757,050 tons; the amount of shipments is, therefore, taken as 1,750,000 tons, the annual value of which is estimated at £620,000.

The following is the recapitulation of the quantities of coal now annually consumed, and the estimated value of the manufactures in the production of which it is employed. The consumption in 1834 is added, so as to show the great increase which has taken place since that period:—

	1834	1847	Value of Products in 1847.
	Tons.	Tons.	£.
Iron works	1,000,000	2,850,000	3,050,000
Copper works . . .	150,000	400,000	2,600,000
Tin works.	100,000	250,000	550,000
Chemical, &c., works and domestic uses . . .	650,000	750,000	180,000
Shipments.	1,100,000	1,750,000	620,000
Totals . . .	3,000,000	6,000,000	7,000,000*

It thus appears, that the consumption of this coal has been doubled since the year 1834; the extension of the iron and

* Some of the foregoing statistical information is derived from two able and very interesting publications by Thomas William Booker, Esq., [Now, (Jan. 1858,) T. W. Booker Blakemore Esq., M.P.,] viz., "The prize Treatise on the Mineral Basin of Glamorgan and adjoining district," 1834; and his "Speech delivered at the Meeting of the British Association held in Swansea, 1848."

copper works, the increase of the shipments, and the progressive introduction of the railway system into the principality, will tend very materially to increase the demand for it and add to the exhausting process now in operation.* Presuming that this coal-field extends over 1,000 square miles, and that it is of an average thickness of 95 feet of workable coal, Mr. Martin calculates, that there are 64,000,000 tons in each square mile; taking, therefore, the consumption at the present amount of 6,000,000 tons per annum, it will require upwards of ten thousand years to exhaust the coal in South Wales. As has been already stated, reasonable doubts may fairly be entertained of the correctness of Mr. Martin's estimates, but supposing there to be only two-thirds, or even one-half of this quantity, still there is an ample supply for ages to come.

The value of the coal now produced, and of the manufactures supplied by it, amounts to £7,000,000 annually; and when it is recollected, that this large sum is chiefly expended in manual labour, some notion may be formed of the vast amount of human comfort which is derived from it, and of the benefits which this mineral district bestows, not only on the United Kingdom but on the whole civilized world.

Having approximately ascertained the available quantity of this coal, its quality is the next subject that demands attention. There are few, if there be any, coal-fields, which contain a greater variety, or fuel better suited to the many purposes for which it is required. About two-thirds of it contain bituminous coal, and one-third is anthracite; a great portion partakes of the nature of both these kinds, and is called 'free-coal,' from its not 'binding,' or caking in the fire. The qualities of each kind are also different and numerous, ranging from highly bituminous to almost pure anthracite, so that the best quality of almost any kind of coal which may be required, can be obtained in this extensive and valuable field.

Coal is shown, by chemical analysis, to be composed of carbon, hydrogen, nitrogen, sulphur, oxygen, and of some earthy matters. These are found to exist in various proportions, scarcely two veins of coal being exactly alike; and a considerable difference is frequently found in the coal from the same vein in different localities. In the coal of South Wales, the carbon varies from 60 to 95 per cent.;—the hydrogen from 3 to 6 per cent.;—the nitrogen from 0·18 to 2 per cent.;—the sulphur from 0·23 to 8 per cent.;—the oxygen from 0·39 to 7 per cent.;—and the ashes from 0·62 to 14

* Mr. Hunt gives the total produce in 1855, as 8,522,270 tons.

per cent.* When these constituents are united in such proportions as to produce the greatest effects on combustion, leaving little residuum, they form the best coal. The greater the proportions of carbon and hydrogen to the other constituents, the better is the coal; and the proportions in which these elements exist, show the relative fitness of the coal for any particular purpose; for instance, the coal required for producing steam, should have a large proportion of carbon, whilst that used for making gas, ought to be rich in hydrogen.† In estimating the value of coal, therefore, especial reference must be had to the purposes to which it may be applied; and in testing the coal of South Wales in this way, it will be necessary to consider its fitness for the smelting and manufacture of metals,—for the production of steam,—for other manufacturing purposes,—for the burning of limestone,—and for household and other miscellaneous uses.

The large quantity of this coal which is consumed in the smelting and manufacture of iron, copper, and tin plates, and the superior quality of the produce, sufficiently and conclusively prove its value for such purposes; and in the following observations upon its several kinds and qualities, ample evidence will be adduced of its fitness for other services, equally important. In this district there is a greater variety of coal than in any other, and the consumer is, therefore, enabled to select that which is best adapted to his object; and although, as in other coal-fields, there is much inferior coal, yet there is a very great proportion of excellent quality. In purchasing coal, consumers should have especial regard to the kind as well as to the quality, otherwise they may be disappointed in the results.

It has been stated, that the value of coal for producing steam, is

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* Penner Vein (Newport)	60·25	Carbon.
Pentyrch Vein (Cardiff)	95·68	
Pentrepoth	0·18	Nitrogen.
Ebbw Vale	2·16	
Ebbw Vale	0·39	Oxygen.
Graigola	7·19	
Jones' Veins	3·46	Hydrogen.
Bedwas	6·01	
Weigfach	0·23	Sulphur.
Tonmawr Isha	8·35	
Cwm Buchan	0·62	Ashes.
Porthmawr Rock	14·72	

† In his Paper on the evaporation of water from steam-boilers, Mr. Parkes says, that he has seen Scotch Cannel coal give out 85 per cent. of gas. *Vide* Transactions Inst. C. E., vol. i., p. 169.

directly as the quantity of carbon it contains; and this opinion is partly confirmed by the Report of Sir Henry De la Bèche and Dr. Playfair on the coal best suited to the steam-navy, and by the statement of Messrs. Parkes and Pellatt,* that they found 9 lbs. of coke equal, in effect, to 12 lbs. of coal. Mr. Pellatt added, that he obtained 70 per cent. of coke from the coal, and as the coke represents the carbon and ashes contained in the coal, the effect produced is attributable to the carbon only. Could this fact be clearly and incontrovertibly established, a certain and ready means of ascertaining the relative value of different coals for steam and other purposes, would be found in analysing their constituent parts. But there are difficulties to be obviated, before an implicit reliance can be placed on this mode of determining the value of coal. A reference to the annexed Table, extracted from the first Report of Sir H. De la Bèche and Dr. L. Playfair, giving the number of lbs. of water evaporated from 212°, by 1 lb. of the several coals named, and the mean composition of their average samples, shows, that although, in the majority of instances, the evaporative power of the coal is in some ratio to its carbon, yet there are several exceptions to this rule. For instance, Nos. 1, 2, 3, 4, 5, 6, 8, &c., show the evaporative power to be in some near proportion to the carbon, but No. 6 evaporates 9·52 of water with 84·71 of carbon, whilst No. 19, with 85·52 of carbon, only evaporates 6·36 of water. Other discrepancies of the same kind may be observed, nor is there anything in the other component parts of the coal at all sufficient to account for the difference in the results, when viewed in reference to the whole. Whether this difference arises from some peculiar property in the exceptional coals, or is to be attributed to some defect in the testing apparatus, it is difficult to determine. It is possible, if not probable, that it may be owing to the latter cause. Referring to the able and very interesting Papers on the evaporation of water from steam-boilers, communicated to the Institution by Mr. Parkes,† it is stated, in the Annual Report of the Institution for 1840, "that in one class of boiler, the same quantity of coal is burnt eight times as rapidly as in another class,—that the quantity consumed on each square foot of one grate, is twenty-seven times that on the grate of another,—that the quantity of water evaporated bears some definite relation to the quantity of heated surface,—that there is twelve times more water evaporated by each foot of heated surface, in one class of boiler than in another,—and finally, that the quantity of water

* *Vide* Minutes of Proceedings Inst. C.E., vol. i., 1839, p. 35.

† *Vide* Minutes of Proceedings Inst. C.E., vol. i., 1839, p. 54, and 1840, p. 6.

TABLE showing the Number of Pounds of Water evaporated from 212°, by One Pound of the following Coals, and the mean composition of their Average Samples.

No.	Locality, or Name of Coal.	Evaporating Power.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Per Cent. of Coke left by each Coal.
1	Ebbw Vale	10·21	1·275	89·78	5·15	2·16	1·02	0·39	1·50	77·5
2	Duffryn	10·14	1·326	88·26	4·66	1·45	1·77	0·60	3·26	84·3
3	Binea Coal	9·94	1·304	88·66	4·63	1·43	0·38	1·03	3·96	88·1
4	Bedwas	9·79	1·32	80·61	6·01	1·44	3·50	1·50	6·94	71·7
5	Resolven	9·53	1·32	79·33	4·75	1·38	5·07	Included in ash.	9·41	83·9
6	Mynydd Newydd	9·52	1·31	84·71	5·76	1·56	1·21	3·52	3.24	74·8
7	Anthracite, (Jones and Co.)	9·46	1·375	91·44	3·46	0·21	0·79	2·58	1·52	92·9
8	Ward's Fiery Vein	9·40	1·344	87·87	3.93	2·02	0·83	Included in ash.	7·04	..
9	Graigola	9·35	1·30	84·87	3·84	0·41	0·45	7·19	3·24	85·5
10	Oldcastle Fiery Vein	8·94	1·289	87·68	4·89	1·31	0·09	3·39	2·64	79·8
11	Llangennech	8·86	1·312	85·46	4·20	1·07	0·29	2·44	6·54	83·69
12	Three-Quarter Rock Vein	8·84	1·34	75·15	4·93	1·07	2·85	5·04	10·96	62·5
13	Pentrepoth	8·72	1·31	88·72	4·50	0·18	..	3·24	3·36	82·5
14	Cwm Frood Rock Vein	8·70	1·255	82·25	5·84	1·11	1·22	3·58	6·00	68·8
15	Cwm Nant-y-gros	8·42	1·28	78·36	5·59	1·86	3·01	5·58	5·60	65·6
16	Coleshill	8·00	1·29	73·84	5·14	1·47	2·34	8·29	8·92	56·0
17	Porthmawr Rock Vein	7·53	1·39	74·70	4·79	1·28	0·91	3·60	14·72	63·1
18	Pontypool	7·47	1·32	80·70	5·66	1·35	2·39	4·38	5·52	64·8
19	Pentrefelin	6·36	1·358	85·52	3·72	Trace.	0·12	4·45	6·09	85·0

evaporated by a given weight of fuel is, in one class, double the quantity evaporated in another." *

Any experiments, therefore, with such an apparatus, must give variable and uncertain results. Different kinds of coal require differently-constructed furnaces to develope their full vaporizing power; and to test a highly-bituminous coal in the same furnace that is used for a free-burning, or anthracite coal is doing a great injustice to the character and capability of one of them. It is well known, that highly-bituminous coal on being thrown into the furnace, suddenly gives out large quantities of hydrogen, which requires a corresponding quantity of oxygen to insure its perfect combustion. In many cases, this is permitted to escape unconsumed, in dense black smoke, and a great portion of the evaporating power is thereby lost. But supposing the furnace to be so constructed as to consume the whole products of this coal, then it is unfit for the use of non-bituminous coal, the combustion of which is slower and more enduring, but which, with too great a supply of air, would burn feebly, without giving out the requisite heat. It will, probably, be found, that the failure of many furnaces in producing the anticipated results, originates from this cause. Sufficient attention does not appear to have been paid to this subject, and the kind and quality of the fuel to be used has not been adequately considered by Engineers, in designing their furnaces and boilers. Of this a striking instance was mentioned by Mr. John Taylor,† at one of the Meetings of the Institution, in 1839:—"Soon after Messrs. Grose had erected, in Cornwall, their famous eighty-million engine, one in every way similar was erected in North Wales. A duty of seventy, or eighty millions was expected. It never rose above forty-five. They tried some Swansea coal,—the duty immediately reached seventy millions. The bituminous effect of the North Wales coal is lost,—it distils off; and this is shown by the fact, that when fresh coal is thrown into the furnaces in North Wales, a cloud of smoke issues from the chimney, but in Cornwall, no smoke is visible." The mode, therefore, of testing the value of coal by ascertaining its evaporative power, must be viewed as uncertain and unsatisfactory, unless special provisions be made in the apparatus to suit the peculiar properties of different coals; and until this is done, it will be somewhat difficult to lay down any precise rule, as applicable to all descriptions that may be tried in this manner. The best proof may, probably, be found in the duty it performs where the coal is best known, and where its

* *Vide* Minutes of Proceedings Inst. C. E., vol. i., 1840, Annual Report, p. 9.
† *Vide* Minutes of Proceedings Inst. C. E., vol. i., 1839, p. 41.

peculiar properties have been duly considered in the mode of using it. Such data cannot always be had, or if obtained, they may not always be relied on as correct; in such cases, an opinion of the value of the coal must be based on an analysis of its component parts, which, in most cases, and until better tests are discovered, may perhaps sufficiently indicate its economical value.

There is a strong prejudice, among consumers, in favour of highly-bituminous coal, although for most purposes, its use is attended with very great waste; a great portion of its gaseous matter generally passes off unconsumed into the chimney, and thence into the atmosphere, to the discomfort and injury of the neighbouring population. On the other hand, a non-bituminous coal, like anthracite, is so difficult to kindle, or inflame, and to keep in an incandescent state, especially in open grates, and requires so much peculiar management, as to be unfit for general consumption. The most generally useful and economical coal, is that which contains only so much of the bituminous property as readily and freely enters into perfect combustion with the carbon, and from which little, or no smoke arises. This description is abundant in South Wales, and only requires to be more generally known to be properly appreciated.

Besides the proportion which the bituminous quality of the coal may bear to the carbon, there are others of its component parts which require notice, for if they are present in too great quantities, they tend materially to its deterioration:—these are the sulphur and ashes. The former is found, with some exceptions, in all coal, and when it is abundant, very seriously lessens its value. For domestic, steam, and manufacturing purposes, such coal is both unpleasant to use and prejudicial in its effects: in ascertaining the value of any coal, the precise amount of sulphur it contains, ought, therefore, always to be carefully determined by analysis. The quantity and nature of the ashes also demand particular attention. The less there is of non-combustible matter, the better and purer, of course, is the coal; for the loss occasioned by a large proportion of ash is not confined to the mere loss of its weight in coal, but it deadens the fire, chokes the interstices, thus preventing the free admission of air, rapidly fouls the flues, and in a dwelling-house, covers the furniture with dust, whenever the fire is stirred. The nature of the ash is generally indicated by its colour, which ought always to be carefully noticed. Upon this subject Mr. Mushet says:*—"As far as the

* *Vide* "Papers on Iron and Steel, Practical and Experimental." By David Mushet. London, Weale, 1840, p. 907.

external appearance is concerned, ashes may be classed under heads of red, brown, fawn, white, and grey coloured; the colouring matter of the red being evidently derived from the presence of iron, which, before burning, had existed in the state of sulphuret. The brown may be considered as deriving its colouring matter from the presence of oxide of iron, sometimes mixed with sulphuret, when passing into red. The fawn colour, which is most common, may owe its colour to the presence of a small portion of carbonate of iron, which, by the admixture of a minute portion of red, sometimes deepens into orange. The white may be considered to denote the absence of colouring matter altogether, but when alloyed with a portion of the red, forms a variety of delicate pink tints. The grey ash may probably owe its colour to a portion of the oxide of manganese being present." In many processes, the colouring matter in the ashes of the coal used, may be very prejudicial, and hence the necessity of carefully noting the colour as well as the quantity of the ashes.

In Mr. Mushet's interesting and truly valuable book on Iron and Steel, there are numerous analyses of the coal of this district in its several localities, of which the Author of the Paper has freely availed himself in the following brief descriptions of the several kinds. To avoid prolixity, and a partial, or unfair selection, an analysis is given of a specimen containing the least carbon, and of another containing the most carbon, with the average result of as many specimens of each kind as the Author has been able to obtain from Mr. Mushet's Papers, and from other sources. These average analyses will give the best notion of the general character of the coal of South Wales, concerning which further information is to be found in the work above mentioned, and in the more recent Report of Sir Henry De la Bèche and Dr. Playfair.

The coal of South Wales may be classed under five distinct heads:—bituminous, semi-bituminous, partially-bituminous, anthracitous, and anthracite.

The bituminous coal closely resembles that of Newcastle; although it has not quite so much bitumen, yet it has more carbon and less ash than the coal of that district. It is not, therefore, quite so good for the manufacture of gas, but for most purposes, it is quite equal to it. The nature and properties of this kind of coal are so well known, as not to require a long description. Its quantity, as compared with that of the other kinds, is only small; and it frequently, if not generally, happens, that highly-bituminous coal passes into the other descriptions on a change of locality, even in the same veins. These variations in the nature of the coal deprive the miner

of any certainty as to its quality on opening a new colliery, and thus, in some measure, increase the risk of these speculations. The following are the analyses of the bituminous coal of this district; the first is stated to be "highly bituminous," and the second "strongly bituminous."

Containing least carbon	Volatile	31·87	Carbon	63 63	Ashes	4·50
Containing most carbon	„	10·31	„	87·69	„	2·00
Average of 57 specimens	„	21·55	„	75·34	„	3·11

The ash of the first was grey, and that of the second, a light fawn colour.

The coal classed as semi-bituminous, is very valuable, and with the exception of making gas, is fit for almost every purpose, as a good and economical fuel. It is sufficiently bituminous to be easily inflamed, and makes a bright cheerful fire, giving out little smoke, and imparting great and lasting heat. The coke, or cinder, of highly-bituminous coal is so soft, that it crumbles, or is broken into such small pieces as to fall through the grate into and among the ashes, from which it is not easily separated; and a great waste of fuel ensues in this way, as well as in the large quantity of combustible matter that escapes from it unconsumed, into the chimney. What the precise amount of the loss thus sustained may be, has not been ascertained, but it must be very considerable. In the use of the semi-bituminous coal, no such waste occurs. The ashes are as easily separated from any partially-consumed matter, as those from wood, or charcoal. The smoke, instead of being black and dense, issuing in large volumes as in highly-bituminous coal, is brown, producing little soot, and is inconsiderable in quantity. It is sufficiently bituminous to 'bind,' or coke, without melting, and makes a bright, glowing fire. For all domestic purposes, it is an excellent and an economical fuel. It is well adapted for steam navigation, and its use in the Government and other steam-vessels, is steadily and rapidly increasing. It makes a good, strong coke, well adapted for the smelting and manufacture of metals, the use of locomotive engines, and for other purposes. In describing this coal, a specimen of which he had chemically examined, Dr. Ure says:—"Of the vast variety of coals which I have analysed, this is the most valuable for the purpose of fuel, either in private houses, or in public works." A considerable proportion of the coal in the counties of Monmouth and Glamorgan is of this description, and the largest quantities of it are shipped at Newport and Cardiff. The analyses of it are as follows:—(in the first specimen the ashes are drab, and in the second of a fawn colour:)

Containing least carbon	Volatile	34·28	Carbon	61·78	Ash	3·94
Containing most carbon	„	10·00	„	88·50	„	1·50
Average of 63 specimens	„	21·40	„	74·66	„	3·94

The partially-bituminous coal partakes of the nature of anthracite, yet still retains some bituminous properties. In this district it is generally known as 'free-burning' coal, from its not 'binding,' or caking in the fire. In many respects it resembles the semi-bituminous coal, and in others, it is like anthracite. For general purposes it is not equal to either of the foregoing kinds, but some of it makes good iron, and it is a good steam coal: it also answers well for lime-burning. It is very abundant in the middle and the eastern portions of the coal-field. In analysis, it closely resembles the semi-bituminous, and its ash is of a light red, and fawn colour.

Containing least carbon	Volatile	33·80	Carbon	61·26	Ash	4·94
Containing most carbon	„	10·00	„	88·13	„	1·87
Average of 17 specimens	„	20·43	„	76·12	„	3·45

The anthracitous coal is the least valuable kind in this district; it has few of the peculiar properties of the bituminous coal, but more nearly resembles anthracite. It is known as 'culm,' or bastard anthracite, and is used principally for lime-burning, for which purpose it is exported to Ireland and other places; but some of the best is used in making iron. The quantity of it is only inconsiderable, and the ash is of a reddish-brown and light-brown colour. The following are the analyses of it:—

Containing least carbon	Volatile	14·26	Carbon	82·99	Ash	2·75
Containing most carbon	„	6·14	„	92·11	„	1·75
Average of 17 specimens	„	9·24	„	88·41	„	2·35

The anthracite of South Wales is of an excellent quality, and possesses all the peculiar properties of that mineral. It burns without emitting flame, or smoke, does not 'bind,' or cake, nor soil the fingers on being handled, and it has a metallic lustre. It is found in great abundance in Pembrokeshire, Carmarthenshire, and in some parts of the county of Glamorgan. Its ash is of a light pink and of a dark-grey colour. Comparing its analyses with those of the anthracites of America and Ireland, it appears to be quite equal to, if not superior in quality to both of them.

Containing least carbon	Volatile	9·00	Carbon	81·00	Ash	10·00
Containing most carbon	„	2·81	„	95·69	„	1·50
Average of 21 specimens	„	7·24	„	90·12	„	2·64

The following Table is a recapitulation of the foregoing analyses.

Kind of Coal.	Containing least Carbon.			Containing most Carbon.			General Averages.			
	Volatile.	Carbon.	Ash.	Volatile.	Carbon.	Ash.	No. of Specimens.	Volatile.	Carbon.	Ash.
Bituminous . . .	31·87	63·63	4·50	10·31	87·69	2·00	57	21·55	75·34	3·11
Semi-bituminous .	34·28	61·78	3·94	10·00	88·50	1·50	63	21·40	74·66	3·94
Partially-bituminous	33·80	61·26	4·94	10·00	88·13	1·87	17	20·43	76·12	3·45
Anthracitous . .	14·26	82·99	2·75	6 ·14	92·11	1·75	17	9·24	88·41	2·35
Anthracite . . .	9·00	81·00	10·00	2·18	95·69	1·50	21	7·24	90·12	2·64

It will be observed, that although the proportion of carbon is sufficiently indicative of bituminous coal and anthracite, yet that it does not constitute a certain and invariable test of the quality of either kind, more especially of the bituminous descriptions. This may generally be more nearly ascertained, by referring to a more complete analysis, in which the component parts of the volatile matter are shown, as in the following instances:—

	Bryn Dewy, Neath.	Lower Grais Vein, Llanelly.
Carbon	79·78	88·06
Hydrogen . . .	4·98	2·71
Nitrogen . . .	1·58	1·06
Oxygen and loss . .	7·16	4·52
Earthy matter . .	5·05	1·20
Moisture . . .	1·45	2·45

In these examples, the semi-bituminous coal is indicated by its greater proportion of hydrogen, and the partially-bituminous, by its excess of carbon; but this cannot be relied on as a universal rule, as a reference to the analyses of Mr. Mushet, and those published by the Ordnance, unequivocally prove.

The most distinctive characteristics of coal may probably be found in the kind, quality, and quantity of coke it produces. The classification previously adopted, has been made on this basis, and derived from Mr. Mushet's work, before mentioned; it is, with some slight alterations, as follows:—

"*Bituminous.*—Those coals which in coking, either in whole, or in part, dissolve and enter into fusion, so as to form an entire and compact mass, are decidedly bituminous.

"*Semi-bituminous.*—When the angles of the cokes are not only

rounded, but the masses have lost their original form, with considerable adhesion of the parts, the coal is semi-bituminous.

"*Partially-bituminous.*—Those coals, which after coking, present the masses with rounded edges, and a slight disposition to adhere together, are partially-bituminous.

"*Anthracitous.*—Coals which do not lose their form in coking, and in other respects partake of the nature of anthracite, are classed under this appellation.

"*Anthracite.*—Properly speaking, this coal does not form a coke, in the usual acceptation of the term. Water and hydrogen are expelled in small quantities during the distillation, and a slight diminution of bulk is sustained, but no new arrangement takes place, as is usual in the transition of coal into coke; the fracture remains the same, and as conchoidal as before, and is without the cellular structure peculiar to coke; a structure to secure which in the most limited degree, would require the coal in coking to evolve at least 10 per cent. of carboniferous flame. When coal is passing into a state of anthracite, it is sometimes found divided into laminæ of flame-coal and anthracite; in coking, the former assumes the cellular arrangement, but the latter remains unchanged as to structure, though a good deal discoloured by the discharge of the gas from the flame-part of the coal."

The vast increase in the consumption of coke, by the establishment of railways throughout the country, and the large sum which is absorbed in this item of expenditure, invest with additional interest, all questions of economy in its production and use. Considerable attention has been paid to this subject as connected with the making of iron; and a saving of from 25 to 100 per cent. of the quantity consumed for certain purposes, has been effected. But the kind and quality of the coke used in locomotive engines, does not appear to have received that consideration which its importance demands; and it is, therefore, a subject urgently requiring the attention of the Institution, with a view of decreasing the expenses of railways. This object may, probably, be best attained by selecting with great care, and in some instances, mixing the kinds of coal used, and by adopting the best process for coking it. In many cases, the choice is necessarily limited by local circumstances, but in others, it may be extended by importing the coal from different places. Highly-bituminous coal, from the large proportion of volatile matter which it contains, not only produces a small percentage of coke, but its quality is much inferior to that obtained from less bituminous descriptions. It is specifically light, spongy, and much honeycombed; it is soft and easily crumbles, and there-

fore, is attended with great waste, and it is less effective in producing steam. The best description of coal for making coke for steam purposes, is that classed as semi-bituminous, 1 lb. of which, it will be seen, on referring to Sir Henry De la Bèche and Dr. Playfair's Report, evaporated upwards of 10 lbs. of water; but as this coal cannot always be obtained at a moderate price, where it may be required, the kind most nearly approximating it in the component parts and easily and cheaply procured, ought to be selected.

The Author has long thought, that anthracite might be used with advantage in locomotive engines, either in part, or altogether. Its tendency to decrepitate, or fall into small pieces when heated, is, however, a serious obstacle to its adoption. It is said to have been successfully tried on the Liverpool and Manchester Railway, in 1838, or 1839;* but as that experiment has not induced the adoption of anthracite, notwithstanding the great saving in the weight of fuel effected, it may be concluded, that the employment of it was attended with other disadvantages not mentioned. Some experiments have been made, with the object of avoiding the decrepitation of anthracite, when put on the fire, by first submitting it to a slow heat, and in other instances, by submitting it to a coking process. Both experiments are said to have been attended with success, but neither have been generally adopted. Further trials will be required, before the expediency of using anthracite in this way, can be satisfactorily proved; and even if this should be established, the carriage, or freight added to the original cost, would probably render it too expensive for many of the railways in the kingdom. The use of anthracite in steam-ships is a subject of great importance, as, if it could be successfully adopted, a great amount of space, now occupied by the stowage of coal, might be saved, and be appropriated to an increased cargo. The necessity for calling at coaling stations, in long voyages, would be decreased, and in some cases, might be altogether avoided. As it has been shown, that 100 tons of anthracite will do the duty of 144 tons of bituminous coal, taking also into account the greater specific gravity of the anthracite, a saving of one-third of the space now occupied for this purpose might be made. Many obvious advantages would also arise from the absence of smoke. In America, anthracite has long been used for marine engines, and with very satisfactory results.†

* *Vide* "The Civil Engineers' and Architects' Journal," 1839, p. 182.

† In 1853, the 'Great Britain' made two voyages to Australia with the Pembrokeshire anthracite, upon which Captain Matthews reported, that "the coal answered the most sanguine expectations, and the fire-bars were by no means deteriorated." The royal yacht 'Fairy' was also frequently supplied with the same fuel.—[J. R., Jan. 1858.]

Some interesting experiments, bearing upon this subject, have recently been made at the Neath Abbey Iron Works, by Mr. Charles H. Waring, who mixed certain proportions of small anthracite with the small of bituminous coal, and coked them together. The produce was a conglomerate coke; for after having been twelve hours in the patent oven, the anthracite appeared unchanged in nature, or quality, but was firmly embedded in the coke of the bituminous coal, which was perfectly charred. It was tried in the cupola at the Neath Abbey Works, on more than one occasion, with the most satisfactory results. Mr. Waring states, that it melted fourteen times its weight of iron, whilst the bituminous coke made from the same coal unmixed with anthracite, only melted, at the most, ten times its own weight. The proportions of coal used, were three parts of bituminous coal to one part of anthracite. Further experiments, which are in contemplation, will show whether the proportions of anthracite may be advantageously increased, or diminished. The iron is said to have been of better quality, to have attained greater fluidity with less blast, and to have been produced with much less dross, than when bituminous coke was used. There can be little doubt, therefore, that this conglomerate coke may be very beneficially used in locomotive engines, and that a saving of at least one-third of the present cost of fuel may be thus effected, in this large item of railway expenditure.

Small anthracite coal is at present in little demand, and may be obtained at Neath, Swansea, or Llanelly, at from 4*s.* to 5*s.* per ton, and the freight to London, and the south and east coasts of England, is from 6*s.* to 10*s.* per ton; it can, therefore, be delivered, for mixing with other coal, on the metropolitan and other railways communicating with the coast, at about the same, or less cost than the bituminous coal of the North of England. The probability of the successful application of anthracite in this manner is so great, and the risks to be encountered are so inconsiderable, as to entitle it to a fair trial, and to the favourable consideration of those Members of the Institution who are interested in the full development of the railway system. There can be no question, but that the superior performances of the engines on the Great Western Railway, are partly attributable to the excellence of the coke, which is made from a semi-bituminous coal from this district; and the extraordinary duties effected by the Cornish pumping engines may also be cited as a proof of its superior steam-producing qualities.

As far as the economical value can be appreciated from analyses,

the following comparative statement clearly indicates the superior quality of the coal of South Wales. It will be seen, that the analyses given are the average results of an examination of one hundred and seventy-five specimens, and that no partial, or unfair selection has been made. Had those specimens which contain the most carbon been taken, the comparison would have been still more favourable to this district.

	Locality of Coal.	Number of Specimens.	Volatile.	Carbon.	Ash.
South Wales.	Bituminous	57	21·55	75·34	3·11
	Semi-bituminous	63	21·40	74·66	3·94
	Partially-bituminous	17	20·43	76·12	3·45
	Anthracitous	17	9·24	88·41	2·35
	Anthracite	21	7·24	90·12	2·64
Forest of Dean		11	35·79	61·64	2·57
Shropshire		8	37·16	60·98	1·86
South Staffordshire		15	42·54	54·53	2·93
North Staffordshire		15	36·17	61·68	2·15
North Wales		28	34·47	62·92	2·61
Derbyshire		14	36·50	60·60	2·90
Yorkshire		21	33·75	64·63	1·62
Scotch (Glasgow)		26	45·64	49·33	5·03
Newcastle-upon-Tyne (Garesfield)		1	25·90	72·71	1·39
,, ,, (Wylam)		1	37·60	48·49	13·91
Irish (Kilkenny Anthracite)		1	4·25	92·87	2·88
American (Lehigh Anthracite)		1	6·60	90·10	3·30

The highest evaporative power of this coal is said to be 10·21, (see Table, page 95), but the average of nineteen specimens being only 9 lbs., the latter number is taken, in the following statement of the comparative value of different coals in producing steam, which is the result of a series of experiments, reported in the 'Atlas;' and it very nearly agrees with the Report to the Admiralty before mentioned.

1 lb. of (South) Welsh coal will evaporate 9 lbs. of water.
,, Newcastle, or Yorkshire ,, 7½ ,,
,, Lancashire ,, 7 ,,
,, Scotch ,, 6 ,,

Therefore, if the value of (South) Welsh coal be 20*s.* per ton
that of Newcastle and Yorkshire is . 16*s.* 8*d.* ,,
Lancashire . . . . 15*s.* 6½*d.* ,,
Scotch . . . . . 13*s.* 4*d.* ,,

It also follows, that 100 tons of Welsh coal, for working and stowing, is equal to 120 tons of Newcastle and Yorkshire, and 150 tons

of Scotch coal. The bulk is estimated in proportion to the evaporative strength; but as the coal of South Wales is from 12 to 15 per cent. specifically heavier than the other descriptions, an addition to that amount must be made on account of the superior facility of stowage.

From the preceding considerations on the quality of the coal, it will be seen, that by whatever test it be tried, it will bear a favourable comparison with that of any other coal-field; and that, with the exception of making gas, it is well adapted for all the purposes to which such fuel is applied. Yet there is one circumstance which materially depreciates its value, and to which the attention of the coal-owners ought to be directed;—the negligence which extensively prevails throughout the whole district, in not separating the coal from shale, stone, earth, and other prejudicial substances, before it is sent into the market. This is attributable to insufficient care in mining the coal, and not 'waling,' or 'picking' these foreign substances out of it, after it has been brought to the surface, and before it is sold, or shipped. It is an evil which is easily remedied and ought to be rigorously attended to; for it not only very materially injures the quality of the coal, but gives that of the whole district a bad name, which it really does not deserve.

The quantity and quality of the coal in South Wales having been discussed, the inquiry remains as to whether it can be produced as cheaply as that of any other district; for however abundant and good the coal may be, the wants of the country would be but imperfectly satisfied, if the cost of fuel was considerably increased. It is, therefore, fortunate, that with the advantages already mentioned, this deposit exists under the most favourable circumstances for mining operations. The whole of the coal measures have been raised towards the surface, by two great faults, in a direction from east to west;—one on the north of the coal-field, which has elevated the whole series of veins on that side;—and another, which forms an anticlinal line, and has raised the coal on both sides of it. The coal is thus made much more accessible than it would have otherwise been. As is well known, the country is mountainous, and is intersected by deep valleys in the course of the numerous rivers, which generally run in a direction from north to south, and by the gorges caused by the streams which supply the rivers, from the east and the west. The stratification of the whole field is much disturbed and broken by numerous faults, slips, and dykes, but as the direction of most of them is north and south, and parallel with the rise and dip, less inconvenience results than if they were in a different direction; whilst the benefits arising from the interruption which they cause to the flow of water over any very great area, tend

materially to economise the expense of working the coal. By far the greatest quantity of this coal, is obtained by mining for it in levels, or adits, driven into the sides of the valleys, the facilities for which are very great; and, wherever it can be adopted, the advantages in allowing the free egress of water and transport of the produce, without the aid of pumps, or machinery, render this mode of mining preferable to any other. There are also sloping headings, or slants, which are driven in at the inclination of the strata, which dip from 5 inches to 18 inches to the yard. The water is pumped, and the trams, or waggons are drawn up these slants, by a steam-engine on the surface. This mode of working by slants, although usually requiring a smaller investment of capital, than sinking pits to the deep, is by no means to be recommended, as the working of the coal is not only more costly, but it also limits the quantity produced, to at least one-half of what may be obtained by a properly-constructed pit, sunk to the deep of the measures. The perpendicular pits are not so numerous as the levels, or slopes, and the deepest does not exceed 150 fathoms. The mode of working generally pursued in this district, is by 'stalls.' Some mines are worked on the Newcastle plan, and others in the broad, or long way, but the former method is the most prevalent.

The cost of getting the coal varies considerably, owing to the peculiar circumstances of each mine, to the methods of working, and to the general systems of management; for there are few undertakings which are so pecuniarily sensitive of good, or bad management as collieries. The whole cost of the coal at the mouth of the level, or pit, may be fairly stated at from 2*s.* to 3*s.* 6*d.** per ton, and in the whole district, the average cost may be safely estimated as not exceeding 2*s.* 8*d.* per ton.† To this must be added the expense of carriage from the collieries to the places of consumption, or shipment, which varies according to the distance and the means of transit, and which is, generally, by far the greatest item in colliery expenditure.

The coals are conveyed on common roads, canals, tramways, and railways. Most of them are rudely constructed and inefficiently maintained, especially all those which belong to the coal-owners; the Taff Vale Railway forms, however, an exception, and is one of the most successful speculations of this kind in the kingdom. The more extended introduction of public railways into the principality, some of which are now in progress, will be advantageous, not only

* Now 3*s.* to 4*s.* 6*d.*—[J. R., January, 1858.]

† Now 4*s.* per ton.—[J. R., January, 1858.]

by giving additional facilities to the traffic, but by inducing a spirit of improvement in the existing means of transit. The canal dues charged on coal are from three-eighths of a penny to three-farthings per ton per mile, and the haulage, with the wear and tear of boats, costs, at least, one halfpenny per ton per mile. The charges on coal conveyed on the Taff Vale Railway, are for dues, two-thirds of a penny, and for engine haulage, one halfpenny per ton per mile. This is considerably lower than the carriage of the coal, on some of the private railways, as may be shown in the instance of one in the neighbourhood of Neath, which communicates with the canal, at about five miles' distance from the shipping port. The railway is rather more than six miles and a half in length, and in its passage the coal has to descend 1,136 feet, by a series of self-acting inclined planes, with gradients of from 1 in 3 to 1 in 5, alternating with 'flats' also descending with the load, and worked by horses. There is an ascending inclined plane rising 132 feet with a gradient of 1 in 5, which is worked by a steam-engine of 40 H.P. The load has, therefore, to descend and ascend 1,400 feet in six miles and a half, and the cost of the carriage of the coal on this mountain railway, is rather more than threepence per ton per mile.

Docks have been constructed at Newport, Cardiff, Porthcawl, Port Talbot, and Llanelly.* Considerable sums have been expended in these works and in improving the navigation of the rivers at Neath and Swansea; and other projects of the same kind are in contemplation, so as to increase the existing facilities for the shipment of the mineral produce of the district.

The prices of the coal obtained depend principally on its size, less attention being paid by the purchasers to quality, than to hardness and comparative freedom from small. The selling prices at the ports, delivered on board the ships, are for small, 4*s.* to 5*s.* per ton,—for 'through and through,' that is, coal as it comes out of the mine, 6*s.* to 7*s.* per ton;† and for large, 7*s.* 6*d.* to 9*s.* per ton.‡ These prices are rather lower than those obtained for coal on the Tyne and Wear; and when considered in relation to its superior steam-producing power, as well as its greater specific gravity, the coal of South Wales is cheaper and much more economical, than that of any other district in the kingdom.

Reviewing the premises, and taking into consideration the extraordinarily large quantity of coal in this deposit,—the variety of

* Docks are in the course of construction at Neath and Swansea.—[J. R., January, 1858.]

† Now 7*s.* to 10*s.* per ton.—[J. R., January, 1858.]

‡ Now 8*s.* to 11*s.* per ton.—[J. R., January, 1858.]

its kinds and qualities,—as well as the cheapness with which it can be procured,—it must be admitted, that when the other sources of supply have become diminished, or are altogether exhausted, the continued maintenance and the increased prosperity of British manufactures and commerce may be sustained for ages, by the coal of South Wales.

The Paper is illustrated by a geological section, (No. 4,384,) showing the stratification of the coal-field of South Wales.

APPENDIX.

TABLE of the COAL produced in GREAT BRITAIN and IRELAND, during the Year 1855.

DISTRICTS.	Number of Coal-mines.	Tons of Coal produced by each Mine.	Tons of Coal Exported to Foreign Countries.	Tons of Coal used for Home Consumption.	Total Tons of Coal produced.
Northumberland and Durham	273	56,452	3,014,372	12,417,028	15,431,400
Cumberland	23	35,250	2,441	808,108	810,549
Yorkshire	333	23,265	78,451	7,669,019	7,747,470
Derbyshire and Nottinghamshire	191	16,049	..	3,065,400	3,065,400
Leicestershire	11	38,635	..	425,000	425,000
Staffordshire and Worcestershire	500	14,646	..	7,323,000	7,323,000
Lancashire	357	25,070	426,139	8,523,861	8,950,000
Shropshire	56	19,333	..	1,105,250	1,105,250
Gloucestershire, Somersetshire, and Devonshire	88	16,257	7,149	1,423,471	1,430,620
England	1,832	25,321	3,528,552	42,760,137	46,288,689
South Wales	245	34,907	1,120,947	7,431,323	8,552,270
North Wales	65	17,307	..	1,125,000	1,125,000
Scotland	403	18,171	246,988	7,078,012	7,325,000
Ireland	19	7,611	..	144,620	144,620
Totals	2,564	24,741	4,896,487	58,539,092	63,435,579

The above quantities are extracted from Mr. Hunt's Mining Records, but they are differently arranged, and a column is added, showing the average quantity worked in each colliery in the respective districts. The results shown by this column are new and interesting, and may be taken as indicative of the state of the coal-trade, and of the comparative amount of capital invested, in each district.

Of the large quantity produced, it appears, that 92½ per cent. is consumed in the United Kingdom, and that only 7½ per cent. is exported to foreign countries.

[J. R., January, 1858.]

Mr. D. Gooch said, the semi-bituminous coal from the Taff Vale district, was used to some extent on the Great Western Railway, chiefly for getting up the steam in the locomotives before starting. The principal objection to its use on the line, was the annoyance to the passengers from the smoke, when stopping at the stations; whilst the train was in motion, no annoyance was experienced. Comparative trials between the best quality of Welsh coal and that from the north, proved their values to be about equal.

Mr. R. Stephenson, M.P., *V.P.*, said, he thought one of the chief points of the Paper, most interesting to Engineers, was the proposal to estimate the value of coal, by the amount of carbon which it contained. It had long been a matter of dispute among chemists, and perhaps was not yet finally settled, whether the amount of heat given out, was in direct proportion to the amount of carbon contained in fuel. He believed, that in the combustion of all simple substances, the amount of caloric given out, was in direct proportion to the oxygen consumed: therefore, as carbon, in all fuel, was the agent that combined most directly with oxygen, it appeared to him, they might be convertible terms; that is, the amount of oxygen consumed, or the amount of carbon contained in the fuel, would be equivalent terms. From the observations he had made on the consumption of coal in steam-engines and locomotives, he believed, that the amount of useful effect might be fairly estimated by the quantity of carbon contained in the coal, always supposing the carbon to be fairly and properly consumed, for on that the whole proposition depended. He believed also, that the discrepancies, among experimentalists, had principally arisen from the fact of coal not being a simple substance, and the various qualities requiring to be consumed, under different circumstances, in order to derive from its combustion the greatest amount of useful effect. In the Cornish engines, where anthracite, or the semi-anthracitous coals were almost universally used, every means was adopted to insure slow combustion; the consequence was, that more duty was obtained, than from any other engines. This must arise from the circumstance of the combustion being more perfect, one atom of oxygen combining with one atom of carbon and no more; for if one atom of oxygen carried off two atoms of carbon, the consumption of fuel would become excessive and wasteful.

Mr. Richardson had alluded to the hydrogen contained in various fuels; but experience had led Mr. Stephenson to the conclusion, that hydrogen in fuel was of no use whatever, as it could only combine with the oxygen, and did so combine, in the proper proportions for forming water. It passed up the chimney, as steam,

carrying off an enormous amount of latent heat, which could only be supplied by the combustion of a large amount of carbon, which would otherwise be usefully employed: that coal, therefore, which contained the greatest amount of hydrogen, would be found the most wasteful, in combustion, since it would not produce its due effect, in generating steam from the boiler.

Some years since, Mr. Hall, of Basford, proposed to use coal in locomotive engines, and an engine was placed at his disposal, on one of the railways; Mr. Stephenson had correct returns made of the results, and found, that the consumption of coal was sometimes actually greater than if it had been previously coked; or in other words, that the duty done by one ton of coal, was actually less than the duty done by the coke which that weight of coal would have produced. Various circumstances were suggested by Mr. Hall, to account for this difference, and it had been argued, that in the process of coking, a large quantity of caloric was given off; that portion, therefore, of the useful effect must be lost, and consequently, it was impossible that as much duty should be obtained from the remaining carbon of the coke as from the original coal. The practical working of the engine, however, had satisfied Mr. Stephenson, that the results were as he had stated, and it also appeared to him, that they could easily be accounted for. The heat spent in coking did, no doubt, absorb a certain amount of carbon, which might otherwise be usefully employed; but the combustion in that process only had the effect of converting into steam, the moisture and hydrogen contained in the coal, and of carrying it off by the chimney. The same process was virtually carried on under a steam-engine boiler, and sometimes with a prejudicial effect; it might, therefore, be as well performed in a coke oven, where the caloric spent did nothing more than convert certain useless portions of the coal, from a solid into an aeriform state; thus it was actually the same thing as using the coke. Another argument was, that a large quantity of heat was obtained from the gas in the streets; that heat, therefore, had been first contained in the coal, and was, consequently, lost by coking. But the answer to this was, that a given quantity of coal had been spent in heating the gas retort, in the process of manufacture, and if all the heat could be removed, it would be fairly represented by the quantity of water which the gas, when in combustion, would convert into steam. The heat imparted to the gas retort was not derived from the coal which was put into the retort to produce gas; it was derived from the coal in combustion under the retort, and the gas given out represented the amount of coal consumed under the boiler. The gas in the streets represented the amount of coal consumed under the

gas retort; it did not affect the coal put into the retort for the purpose of making gas. Arguing on these premises, he was satisfied, that the value of coal depended, in the first place, on the quantity of carbon which it contained, and in the second place, on the mode by which it was consumed; some qualities of coal requiring slow, and others, very rapid combustion.

Mr. Woods was cognisant of the circumstances of the original experiment on the Manchester and Liverpool Railway, with the anthracite coal, alluded to by Mr. Richardson. The draught up the chimney was so strong, that the coal was projected into the air in fine powder, and the carriages were loaded with it. The dust was found to be exactly in the same state as the coal before it was put into the fire.

Mr. E. Woods stated, that the experiment alluded to was made by him, on an engine called the 'Swiftsure,' and the result was, as had been stated by Mr. Stephenson, that the anthracite, as soon as it was put in the fire, became a fine powder, choking the bars and tubes, and falling upon the carriages. The experiment was, perhaps rather injudiciously, tried with a first-class train;—the steam was raised in the ordinary manner, and on starting from Liverpool the engine was fed with anthracite; but before the train arrived at Rainhill, there was scarcely steam enough to ascend the inclined plane, and soon afterwards the engine stopped; on feeding it with coke, the train, after some delay, arrived at Manchester. A little alteration was then made in the fire-bars of the engine, and it took back a goods train at an increased speed, but the same general results were observed;—the bars and tubes were choked, and the steam could not be generated at the usual rate. In theoretical experiments, it had been found, that the quantity of water evaporated by one ton of ordinary coal was less than the quantity evaporated by anthracite.

In answer to questions, Mr. Woods said, he did not think, that any correct experiments had been made, for determining the proportion between the water evaporated by a ton of raw coal, and that evaporated by the coke which the same weight of coal would produce.

Mr. Wyndham Harding said, that De Pambour mentioned some experiments on that point, the result of which was, that coke produced as much heat as the coal from which it was made. It would be interesting to institute experiments on the comparative duty performed by the fuel consumed in a good locomotive, and that in the furnace of a Cornish engine, so as to ascertain whether the difference of the useful effect was as great as would, at first, appear to be the case.

Mr. E. Woods said, in a large number of experiments, it was found, that 1 lb. of the best Lancashire coal evaporated 7½ lbs. of water, which was about equivalent to 8½ lbs. of water evaporated by 1 lb. of coke at the temperature of 212°. Some of the Cornish boilers were stated, by Mr. Parkes, to have evaporated 11 lbs. of water; whether it was evaporated under simple atmospheric pressure, or under high pressure, the quantity of heat in a given weight of steam would be very nearly the same.

Mr. R. Stephenson, M.P., *V.P.*, said, it was an established fact, that the quantity of latent heat in 1 lb. of water, whether the temperature was 212°, 300°, or 500°, was the same. The latent heat of steam which was evaporated at 212°, was generally said to be 1,000°; but if it was generated under a pressure of, say five atmospheres, the sensible temperature would only increase in the ratio of the diminution of the latent heat. The amount of heat contained in a given weight of water was known to be a constant quantity, within all practical limits.

Mr. Glynn said, that when he attended the Meeting of the British Association, at Swansea, he went with a party to the iron-works at Ystalyfera, in Glamorganshire, the furnaces of which were entirely fed with anthracite. He had collected several pieces, which had been put in at the top of the furnace and had come out at the bottom, perfectly raw in the centre, after having been exposed to a heat sufficient to melt the iron ores, the combustion not having gone beyond the surface of the lumps, for on breaking them, the coal was found to be exactly in the same state as when thrown into the furnace. Pieces as large as half a brick were constantly picked up, and being collected, were taken to the top of the furnace and again used as fuel. The weight of coal consumed by five furnaces, in blast, was about 80 tons per day: 2 tons of anthracite would produce 1 ton of iron, and the produce of iron from the five furnaces was about 40 tons per day. He had measured the blast-cylinder and found the weight of air, required to consume that quantity of coal, to be about 705 tons, in twenty-four hours.

Anthracite was not, at first, considered to be of any value for smelting iron, until Mr. Neilson introduced the use of hot blast, which was then applied by Mr. Crane, to making iron with anthracite. At the works he visited, they had a licence to use this system; but Mr. Budd, the Manager, soon conceived the idea of utilising the immense volume of heated air and vapour emitted from the top of the furnace, and he therefore conveyed the hot vapours, through tunnels, into proper chambers containing the usual heating apparatus, so as to heat the blast before it went into the furnaces.

Mr. Enys had obtained permission to make experiments for a month, with the coal in question, at the Consolidated Mines, and the result was, that the duty of the engine was as nearly as possible the same with the anthracite, as with the common Swansea coal. He was not present at the trials, but he was told, that the cinders of the anthracite came out of the furnace as bright in the centre as as when the coal was first thrown in; some of the Captains of the mines stating, that one-third, and others, that one-fourth was not burnt. The fire-places were not suited for anthracite, but the men were of opinion, that if more air was given to it, it would burn with great advantage. Mr. Enys always estimated the practical useful effect of coal to be in the ratio of the carbon contained in it.

Dr. Lyon Playfair said, that one of the most important questions for Engineers was, whether the evaporative power of the fuel was dependent upon the quantity of carbon it contained, or whether the hydrogen had any power in the coal consumed; and he was of opinion, that Mr. Stephenson's remarks on that point were correct, both in theory and in practice. To the Engineer the combustion of coal was a very simple affair, as he only looked at the final results,—the conversion of the carbon into carbonic acid, and of the hydrogen into water;—but to the chemist there was a great variety of products to be accounted for, such as the water produced, carbonic acid, carbonic oxide, ammonia, sulphuretted hydrogen, creosote, naphtha, paraffine, picamar, eupion, &c., all of which must be considered, before the question could be finally determined. It was well known, that most of those substances required a high temperature for their formation, and that the heat necessary to consume them was nearly the same in amount as that which was rendered latent in their formation; that was a theoretical result which was to be obtained by calculation. In the Report made by Sir Henry De la Bèche and himself, they had entered largely into that question, and had shown, that the evaporative value of fuel obtained from the coal-field of South Wales was about the same as would have been obtained from the coke, into which that coal might have been converted. Dr. Fyfe, of Edinburgh, had, a few years ago, made some accurate experiments on this subject, and had arrived at this result, that the quantity of water evaporated by a pound of coal, was nearly the same as the quantity of water evaporated by that pound of coal, when converted into coke; the same result had also been obtained in America. Generally speaking, coke had as great an evaporative power as the coal from which it was produced, and the more bituminous the coal, the greater was the evaporative power of the coke. That, however, was not the whole question; it was the

result with regard to the evaporative value, but not the practical result, because a certain quantity of coke would not, necessarily, have the same effect as the coal from which it was produced, so far as regarded to the naval service, for example. If a fire was well lighted up, coke might answer, in evaporating a certain quantity of water, but it might not serve the purpose of getting up the steam quickly, and for some of the exigencies of the naval service, it was absolutely essential, that the fuel should be a quick generator of steam, and that it should continue to produce it with economy. Therefore it was advisable, for naval purposes, not to have the fuel altogether carbonaceous, but to have it so far bituminous as to produce flame, and then if it was considered desirable to have another coal to keep up the heat without flame, coke, or a fuel equivalent to it might be used.

The present system of using fuel in large towns might possibly be changed, with advantage: if in the manufacture of gas, coal was not heated so much as was now the practice, a richer gas would be obtained, and the residual coke, being more hydrogenous, would be useful for many manufacturing purposes. This supposed, that gas was much more extensively used than at present, and that it was applied for purposes for which it was well adapted, when properly employed, such as for heating apartments, for cooking, &c. The less-carbonized coke could be burnt in manufactories, and would prevent the nuisance of smoke, with which all large towns and cities were afflicted.

There was another point, with reference to the density of the coal, which was of importance, especially with reference to its adaptation for export, and for naval purposes. Two descriptions of coal, each evaporating 9 lbs. of water per lb. of coal, would often differ 20 per cent. in bulk; a sea-going vessel could take 80 tons of a coal that evaporated 9 lbs. of water, but it could, in the same bulk, take 100 tons of another coal with an equal evaporative power. This was of the utmost importance for steam-vessels going on a long cruise, in regions distant from coal depôts.

Mr. GLYNN would add to his former statement, that the blast, before it entered the furnaces, attained a temperature of 600°, which was sufficiently hot to melt lead. An iron plug about one inch in diameter being drawn out from the side of the blast-pipe, and a strip of lead about one inch in breadth and $\frac{1}{16}$th of an inch in thickness, being held in the stream of hot air issuing from the hole, it was fused almost immediately.

Mr. Budd did not attempt to produce complete combustion of the heated vapours, by mixing them with atmospheric air, as had been

attempted in the French iron-works; but he contented himself with using the heat carried with the vapours, which was more than sufficient for all his purposes. His mode of applying this heat, hitherto wasted, had been completely successful, and had resulted in an economy of about £3,000 per annum; for it should also be stated, that the heated vapours were employed to work the boilers of the blast-engine, one boiler only being heated with a coal-fire, so as to raise steam independently, in case of any derangement of the apparatus, or a stoppage of the furnaces.

The materials used to make one ton of pig-iron were:—

The mineral,—a clay ironstone, containing about 40 per cent. of iron .	2½ tons.
The flux,—a mountain limestone .	¾ ,,
And the fuel,—anthracite . .	2 ,,
Or a total charge of .	5¼ tons.

There were five furnaces in blast, each making 8 tons of iron, or on the whole, 40 tons per day, so that the daily consumption was:—

Of ironstone (roasted) . . .	100 tons
Of limestone	30 ,,
Of anthracite	80 ,,
Or the total weight of materials .	210 tons.

To smelt these materials, a powerful steam-engine was employed, which worked a double-acting blowing-cylinder, 105 inches in diameter, with a stroke of 10 feet, making twelve strokes per minute. The capacity of this cylinder was 601·32 (say 600) cubic feet, and being double-acting, it was filled twenty-four times in a minute; it discharged, therefore, into the furnaces 864,000 cubic feet of air in each hour, making the quantity consumed, or decomposed in twenty-four hours, equal to 20,736,000 cubic feet blown into the furnaces at a pressure of 4 lbs. on the square inch. Atmospheric air contained, by measure, 20 parts of oxygen, and 80 parts of nitrogen; and by weight, from 22 to 23 parts of oxygen, and from 77 to 78 parts of nitrogen. If the weight of the air was estimated at the mean density of 1⅛ or 1·22 ounce to the cubic foot, it would amount to 705·85 tons per day, whilst the solid materials amounted only to 210 tons. But of this weight, 80 tons were anthracite, which contained from 80 to 90 per cent. of carbon, and not more than from 5 to 10 per cent. of earthy matter, so that nearly the whole of this

weight was rendered volatile. The constituents of mountain limestone were per ton :—11 cwt. 1 qr. 4 lbs. of lime, and 8 cwt. 2 qrs. 24 lbs., or 44 per cent. of carbonic acid: 30 tons of limestone contained, therefore, about 13 tons of carbonic acid which was also set free in the blast furnace. Thus the volume of vapour and the quantity of heat carried off were enormous, and as the great bulk of this vapour was nitrogen, which answered no useful purpose in the furnace, but must be raised to a high temperature, the utility and value of Mr. Nielson's invention were manifest, and the importance of Mr. Budd's plan was also evident.

Analyses of these vapours taken from two openings in the side of the blast furnace, one near the top, about a foot below the surface of the materials with which the furnace was charged, and the other about 16 feet below, were made by Dr. Schafheutl; and at the higher level they were found to consist of

Carbonic acid	9·546
Ditto oxide	12·012
Hydrogen	21·273
Light carburetted ditto	2·548
Sulphurous acid with traces of arsenicated and phosphuretted hydrogen	0·116
Nitrogen	54·505
Total	100·000

And at 16 feet below the former level, of—

Carbonic acid	0·136
Ditto oxide	18·974
Hydrogen	27·844
Light carburetted ditto	3·202
Sulphurous acid with traces of arsenicated and phosphuretted hydrogen	traces
Nitrogen	49·844.
Total	100·000

Sir Robert Kane, in his excellent work "On the Industrial Resources of Ireland," observed, that if anthracite was used under a steam-boiler, the heat might become sufficiently strong to melt away the bars of the grate, and to burn out the bottom of the boiler; and yet the air passing into the flues might not be of such a temperature as to produce an evaporation by any means economical. This disadvantage might, however, be obviated by passing the vapour of

water through the mass of red-hot anthracite; the water was decomposed, its oxygen combining with carbon to form carbonic oxide, while its hydrogen was set free. These mixed combustible gases passed into the flues, ignited in the excess of air which entered, and gave a sheet of flame which would sometimes extend for 30 feet under and through a boiler.

Anthracite was thus converted into a flaming coal. There was no loss of heat, neither was there any gain of heat as some had supposed, but the action was most beneficial in its results, absorbing, in the first place, the excess of heat which was doing local injury, and distributing it over the entire surfaces of the flues, where its maximum of good could be obtained.

The three following specimens of anthracite, analysed by Sir Robert Kane, contained :—

	The Rushes.	Pollough.	Sweet Vein.
Carbon .	90·04	81·36	86·37
Hydrogen .	3·50	2·41	3·71
Oxygen .	2·73	6·34	1·40
Ashes .	3·73	9·89	8·52
	100·00	100·00	100·00

February 20, 1849.

JOSHUA FIELD, President, in the Chair.

No. 799.—"On the Explosion of Fire-damp which occurred in the Eaglesbush, or Eskyn Colliery, near Neath, South Wales, on the 29th of March, 1848."* By Joshua Richardson, M. Inst., C.E., F.G.S.

This melancholy accident happened about two o'clock in the afternoon of Wednesday, the 29th of March, 1848, when twenty men and several horses were killed, and the works were injured to a serious extent. It excited very great interest in the neighbourhood, and in consequence of the frequent occurrence of such explosions in that colliery, there was a prevalent and earnest desire, that the authori-

* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

ties should institute a searching investigation into the state and circumstances of the mine.

During the last four years, upwards of seventy persons had suffered by these lamentable catastrophes, but in none of the explosions had the fatality been so great as in this instance. There was, in consequence, an opinion, that sufficient means were not used to prevent the recurrence of such accidents, and that the lives of the colliers were exposed to unnecessary risks. The coroner and the magistrates of the district promptly responded to the desire of the public, and application was made to Sir George Grey, the Secretary of State, requesting the Government to depute some one to inspect the mine and assist in the inquiry about to be instituted by the coroner's jury. In consequence of these applications, Mr. Warington Smyth was sent down to Neath, and attended the inquest for two days, making also a careful personal inspection of the colliery. He refrained from the expression of any opinion, and declined giving any evidence to the jury, as to the state of the mine, and the probable cause of the explosion; stating that this course was prescribed in his instructions, and that the result of his inquiries would be embodied in a Report addressed to the Secretary of State, which might, or might not, be afterwards printed for Parliament. The Author is not aware whether this has been done, but if so, from Mr. Smyth's extensive knowledge of mining operations, both in this and other countries, and his great scientific attainments, the Report must, doubtless, be an interesting and valuable document.

In consequence of the absence of the coroner, a jury was not impanelled until the 4th of April. It was constituted of the merchants and most respectable tradesmen of Neath, and sat five days, viz., the 4th, 6th, 7th, 16th, and 18th of April, in the Town Hall, and was numerously attended by the Magistrates, Clergy, and inhabitants of the district, as well as by a great many colliers from the adjacent mines. The unsatisfactory and inconclusive nature of the evidence given by the overman and colliers employed in the mine, determined the jury to obtain professional assistance, and they appointed Mr. Bevan, (late, and for twenty years, viewer of the Cwm Afon Collieries,) and the Author to inspect the mine, and subsequently, to give evidence as to its state and the efficiency of the means in use for its ventilation, and professional opinions on the probable cause of the accident.

Ample opportunities were thus afforded for obtaining correct information; and, in order to communicate it as circumstantially and briefly as may be consistent with perspicuity, it is desirable to consider the subject under the following heads.

1°. A description of the colliery and works;
2°. The state of the mine before the explosion occurred;
3°. The state in which it was at the time of the inspection;
4°. The probable causes of the accident; and
5°. The best known means of preventing the recurrence of explosions.

1°. Eaglesbush, or Eskyn Colliery, is situated about one mile and a half south of Neath, and is one of the oldest and most fiery mines in the district. The area of the whole underground works covers about sixty acres. The colliery is worked on the stall system, as shown in Plate 5, which is a copy of the working plan, and exhibits the works as they were on the morning of the accident. The air-course then in use is coloured red, the drifts, headings, and stalls in work, are numbered, and the solid coal is shown black.

The seam, or vein of coal, is 4 feet in thickness, and is divided into an upper and lower coal, by a stone-band which varies from 1 foot to 15 feet in thickness. It is of the latter thickness for only a small space, and swells out gradually on every side, the coal still being found; and it has been worked above and below it. The coal is of a highly-bituminous nature, but is so friable as to produce only a limited proportion of large coal; being, however, of a good coking quality, the small, or dust, is valuable. The strata dip to the north-east by east, at an inclination of about 7 inches to the yard.

The entrance, A, is by a drift 6 feet in height, and 5 feet 6 inches in width, driven in a straight line in the coal, and dipping with it for a distance of about 880 yards. The coal is drawn up this inclined plane by a stationary engine, placed on the surface, near the entrance, in trams containing about 25 cwt. each, moving on a railway of the gauge of 3 feet 2 inches. The cross-headings are driven generally at right angles with the drift-heading, and nearly on a level; only rising sufficiently to drain off the water. The cross-headings are 100 yards apart, and of the same area as the drift. Horses are employed to convey the coal from the stalls to the engine-incline in the drift-heading. The stalls are driven from the cross-headings to the 'rise' of the coal, and are at nearly right angles with the cross, and parallel with the drift-headings. They are 6 yards wide, from 50 yards to 80 yards long, and about 5 feet in height. Pillars of coal, of the same dimensions as the stalls, are left to support the roof, and are removed, or as many of them as is practicable, when the whole of the coal in the heading has been 'holed,' or 'stalled.' These were the dimensions originally designed, but they are not very strictly adhered to in working; yet, on the

whole, this is one of the best-designed and best-worked collieries on this system existing in South Wales.

The ventilation is effected by having downcast and upcast shafts. The downcast shaft, B, is the main pit of the old colliery, and being to the dip of the greatest part of the present workings, the water is drained to and pumped up this shaft by a water-wheel and a steam-engine. After passing down this shaft, the air proceeds along the old headings of the abandoned works in one volume, through such parts of the works as is required, being guided by stoppings and trap-doors, then continues its course to another old shaft, C, which it ascends, there enters a culvert built on the surface of rising ground, and continues to, and ascends a stack, or chimney, at D. At the bottom of this chimney there is, or was, (for it is in a very dilapidated state,) a furnace, of a very imperfect design and limited size. It has been very rarely used, and was, in fact, almost abandoned.

The areas of the air-courses appear to have been determined by accident, and no attempt has been made to construct them on any general, or uniform plan. The area of the downcast shaft is 72 square feet, and that of the air-way through the old workings is 24 square feet, whilst through the present workings it is only 11 feet; the upcast pit is 28 square feet, and the culvert and chimney are 20 square feet. The chimney is 50 feet high from the ground, and its top is 300 feet above the top of the downcast pit. The air is kept in its course by stoppings and doors. Most of the stoppings are formed by two dry stone walls, with a space of 6 feet between them, filled close up with rubbish and small coal. A few of the stoppings were made of stone walls 2 feet in thickness, laid in mortar, and backed by a depth of 6 feet of rubbish. The doors are only single, and are too slightly constructed. The air is conducted to and through the working stalls by bolt-holes made from one stall to another; and as the work advances, additional holes are made, and the lower ones are stopped or 'gobbed' up. The number of these holes depends on the state of the air in the stall, much more fire-damp being given out in some parts of the mine than in others. No means are adopted to direct a current of air beyond the line of the bolt-holes, when the face is further advanced, and the gas, in consequence, accumulates at the upper end of the stall, when the men are obliged to use wooden frames of about 1 square foot to 2 square feet in area, with canvas stretched over them as fans, to drive the fire-damp towards the bolt-holes. The making of these holes adds two pence per ton to the cost of the coal, which amount is sometimes included in the price paid for cutting, or hewing, and in other cases it is paid

separately. Some parts of the air-way are formed by the side of the headings and drift, being separated from them by a stone wall laid in mortar; these air-ways are only 2 feet 8 inches high, and 4 feet wide. No air is passed through the waste, or abandoned stalls, nor are the exhausted parts of the colliery ventilated. The whole distance the air has to travel in the mine, is one mile and five furlongs.

The farthest portion of the colliery is now full of water, for although it does not make any considerable quantity, yet as these parts are below the level of the bottom of the pumping-shaft, the water has accumulated. It is proposed to remedy this inconvenience by sinking the 'sump' under the shaft several fathoms deeper. This has been commenced, and the water has been slightly diminished.

The railway is throughout of the same gauge of 3 feet 2 inches, from the colliery to the shipping wharf at Briton Ferry, a distance of one mile and three-quarters. It descends to the port, and three horses take twelve full trams, weighing 25 cwt. each, and bring them back when emptied. The coal which is filled into the trams in the mine, is not emptied until it arrives at the vessels waiting for it, so that much labour and breakage are avoided. The quantity of coal annually shipped from this colliery is about 30,000 tons, and the land sale, for home consumption, is also considerable.

2°. From the evidence of the colliers employed in these works, it was proved, that this mine was, at all times, much infested with fire-damp, and that it was more than ordinarily prevalent on the Saturday, Monday, and Tuesday immediately preceding, as well as on the day (Wednesday) of the accident. It was stated, that frequent complaints of the bad state of the pit had been made by the men to the overman, and that an explosion had occurred about a week previously, when a man was severely burnt; that the ventilation was always bad in windy and foggy weather, the air in the mine at such times became either quite stagnant, or moved slowly backwards and forwards, instead of proceeding in the proper direction, and that on such occasions the fire-damp was very prevalent. Notwithstanding these unequivocal premonitory indications of danger, no extraordinary means were resorted to, either by lighting the furnace, or in any other way attempting to improve the ventilation, save by the completion of a small air-way, at E, which was in progress, and was finished in the night preceding the explosion. The object of forming it was, to bring the fresh air closer up to the face of the work, at the end of the cross-heading; but no addition to the usual quantity of air was obtained by it, and it was a remedy

by no means commensurate with the necessities of the case, as was proved by the lamentable result. It was also stated, that on previous occasions, when the air was bad in the mine, the whole of the water which was pumped up was suffered to fall down the pit again, and that by this means the ventilation had been decidedly improved.

Although the mine was in such a fiery state on the preceding Saturday, as to oblige the men to leave their work at a much earlier hour than usual, no attempt was made to improve the ventilation. A quantity of water which makes its way into the downcast shaft, is allowed to fall to the bottom, and great reliance appears to have been placed on this circumstance, as a sufficient means of ventilation. There is no doubt, that some good results from the water cooling the air, and from its impact on it; yet there can be no question of the total inadequacy of such measures to effect a thorough ventilation of fiery mines.

The most dangerous part of the colliery was stated to be the middle cross-heading, where the work was in progress, and there is little doubt that the accident originated in the eighteenth stall of that division, and the whole of the men and horses which were in it were killed. There were two distinct explosions, the second following the first after the lapse of about a minute. They were described by the witnesses as "louder than the loudest thunder," and were heard to a great distance on the surface. The overman, who was at the time standing at the entrance of No. 1 cross-heading, was lifted from his feet and thrown to the ground with great violence, to a distance of three, or four yards. The second explosion was most probably caused by the concussion of the air throwing down one of the dry wall stoppings and liberating the magazine of gas contained in the stall, which would, of course, immediately ignite and explode on coming into contact with the mass of flame in the heading.

The impolicy of constructing these stoppings of dry stone walling is shown by the fact, that nearly all of them in this heading were thrown down by the explosion, whilst those built of masonry stood firm. The dry wall stoppings are also a constant source of trouble and expense, as well as of danger; for the rats and mice are continually making holes through them, by which the gas escapes out of the stall into the heading, and men are required daily to examine these walls and to stop up the holes.

Notwithstanding the fiery character which has always been ascribed to this colliery in the district, the managers have never found any difficulty in obtaining the requisite number of workmen,

at the usual wages. This circumstance may be explained by the evidence of one of the surviving pitmen, who narrowly escaped destruction on the recent explosion, and who stated his intention of resuming his work in the mine; he said, that "he had worked twenty years in collieries. The coal is always easier worked when there is foul air than where there is not; it is lighter, and loosened in consequence of the foul air." There was only one witness, and he was described by the deputy-overman as "a fearful fellow," who expressed a determination not to work in the mine again, and in coming to this resolution, he acknowledged he was not influenced by the state of the colliery, but "because of the weakness of the flesh."

Candles, common lamps, and Davy lamps are all used in this colliery. In the fiery parts of the mine, the Davy lamp alone is used; but there are no stringent regulations to enforce the observance of even ordinary care respecting it. Evidence was given to the effect, that it was a common practice with the men to remove the gauze from the lamp, even when its flame indicated the presence of fire-damp,—that they had been frequently seen to do so by the overman and others,—yet nothing beyond a mere reprimand had been inflicted on them. On the morning of the accident, the overman saw one man, (who was afterwards killed by the explosion,) with the gauze cylinder off his lamp, and although the mine was in a very dangerous state, all that the overman did, or intended to do, if the accident had not happened, was to request the man to replace the gauze on the lamp. It was also proved, that whenever the wire-gauze became red-hot, as frequently occurred, the men were in the common practice of retiring to a short distance from the place of work and there taking off the gauze, and of leaving the lamp burning and unprotected, until the cylinder was sufficiently cooled to be put on again. No one had been fined, dismissed from his employment, prosecuted according to law, or otherwise punished for offences of this description. After the explosion had occurred, a Davy lamp, without its gauze cylinder, was found in the twenty-third stall, and another similarly unprotected in an adjacent stall.

3°. In entering a colliery for the first time, and after so destructive an accident as that under discussion, it is not to be expected, that any correct notion of its usual state can be derived from its inspection. If the visit is made immediately after the explosion, little can be seen but the débris of the devastation. Broken doors, prostrate walls, and passages choked with rubbish, are to be seen at every step towards the dangerous recesses which it is most necessary to examine; whilst the atmosphere, owing to the derangement of the means of ventilation, is so strongly charged with fire-damp, as

reasonably to excite apprehensions for personal safety,—a state of feeling by no means conducive to that fearless and patient examination which such an investigation necessarily requires. On the other hand, if the inspection be delayed until the wreck is all removed and the damages repaired, the colliery appears in a better state than it has probably ever been in before. The natural effect of such accidents, for a time at least, is to excite a greater vigilance and exactness in attending to the preventive means in use, and it is not until after the immediate effect of the accident has ceased to operate, that the mine is suffered to relapse into its previous and ordinary state.

The only benefit, therefore, which can accrue from an official inspection of a mine after the occurrence of such an accident, is the knowledge thus obtained of the plan and general design of its several works, especially such as relate to the ventilation, so as to determine how far the safety of the men is provided for, and whether the accident was owing to any defect in the system of working, or ventilating the colliery; or may be attributed to the carelessness of the men themselves, or to some other cause.

In this instance, the inspection did not take place until the 13th of April, a fortnight after the occurrence of the explosion, and Mr. Bevan and the Author were accompanied by the Government Inspector, Mr. Warington Smyth, Mr. William P. Struvé, (on behalf of the owners), and by one of the proprietors, as well as by the overman of the colliery. It is but fair to the owners to state, that they rendered every assistance required, and placed at the disposal of the examiners all available facilities for making a thorough inspection of the works, and obtaining the requisite information.

On entering the colliery it was seen, that most of the rubbish caused by the explosion had been removed, the broken trap-doors had been replaced by new ones, many of the walls and stoppings had been solidly rebuilt with stones laid in mortar, and others were in the course of being erected. There were thirty men and two horses engaged in these repairs. There were no men working coal in any part of the mine. With the exception of a short piece of air-way having since been made, from the fourteenth stall to the air-way F, (as shown by the dotted line,) the colliery remained, as to plan, precisely as it was on the day of the accident.

The mine appeared, generally, in a safe and healthy state; in no part of it was the presence of fire-damp indicated by any change in the flame of the Davy lamp. In one stall it was heard issuing out of the solid coal, making the usual hissing sound; but on placing

the lamp as near as possible to the supposed place of its ingress, no change took place in the flame.

Before entering the colliery, the temperature of the air on the surface was ascertained to be 55°. When tried in the air-way, at a place shown on the plan by the letter H, near the end of the old and the beginning of the new works, it was 62°. The temperature of the air in the new piece of air-way, at F, after it had passed through all the works in progress, was 65°. It was thus shown, that the air on entering the new works was 7° warmer than it was on the surface, and that it only gained 3° in its passage through the works; the ascending column of air being only 10° more rarefied than the descending column.* But it is probable, that the increase of temperature caused by the air having been used, is somewhat less than on ordinary occasions, as there was only about one-half of the usual number of men employed in the colliery at the time these observations were taken, and none of them were cutting coal, or performing such laborious work, as to induce that profuse perspiration and great animal heat which is generally produced by the hewer's occupation. There were also fewer horses than usual in the mine; whilst both the in-let and out-let air-ways had just been cleared of all falls from the roof, or sides, and other obstructive matters, so that a course more than ordinarily uninterrupted admitted a greater quantity of air and gave it a freer exit.

It has been already stated, that a culvert and chimney were erected in 1845, at a cost of £500, for the purpose of improving the ventilation, but so small and imperfect a furnace was made, that it was at first only occasionally used, and it has been so long abandoned, and is now in so ruinous a condition, as not to enter into a consideration of the means of ventilation now in use. The advantages said to be obtained by this culvert and chimney were, that owing to the increased height, (300 feet above the top of the downcast shaft,) the return air would make its exit from the mine into a rarer atmosphere at this elevation. Entertaining considerable doubt as to the reality of this supposition, experiments were made, which

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* The increase of temperature in the upcast, as compared with that in the downcast shaft, it is generally admitted, ought to be, and is generally in well-ventilated colleries, from 30° to 60°. The several temperatures, however, in the Jarrow Colliery, which may be taken as an extreme instance, are stated to have been in the year 1820,—

At the surface	46°
At the bottom of the pit, 146 fathoms	61°
Return air, after having travelled through the workings .	75°
Engine boiler-house, 700 yards from the shaft	144°

showed, that the temperature of the atmosphere at the top of the downcast shaft, and at the base of the chimney, which is 50 feet high, to be exactly 58° at both places. On entering the culvert through a small door near the base of the chimney, the temperature of the air passing in the culvert was only 56°; that is, instead of being more rarefied, it was actually more condensed than the air on the outside. It is clear, therefore, that the effect of these erections, or proposed improvements, must be the reverse of what was anticipated, and of what is usually sought to be obtained in mine-ventilation. The 10° increase of temperature which the air acquired in passing through the colliery is evidently dissipated in its progress towards the chimney, and owing to some imperfect stoppings, it probably escapes in some other direction than is intended. Under such circumstances, it is not surprising, that the air in the mine should occasionally "become stagnant, or move backwards and forwards;" on the contrary, it ought to be more frequently stagnant and oscillatory, and there would be great difficulty in giving it anything like a constant motion in one direction. A system of ventilation so directly and frequently affected by atmospheric changes, cannot be otherwise than very imperfect, and in fiery mines, replete with danger.

Not having an anemometer, or other means for ascertaining the velocity of the air in the mine, the following expedient was resorted to, which, although producing only a probable result, may serve as an approximate datum. It is stated by Mr. Coombe, that air, passing at a velocity of 5 feet per second, will blow out a candle, or any other unprotected light. Presuming this to be a fact, the air was first tried at H, where it enters from the abandoned into the present works, and it was found, that although the flame of the candle was blown from the perpendicular to an angle of about 30°, yet it burnt steadily in that position; it was, therefore, concluded, that the velocity of the air in this place was considerably less than 5 feet per second. The area at this place was 24 square feet. It was next tried at the new piece of air-way; there the flame was driven to a horizontal position, was with difficulty retained, and on moving slowly forwards, it was blown out; it was, therefore, presumed, that at this place the air was passing at a speed of 5 feet per second, and the area being 10·64 feet, it was calculated, that 53 cubic feet of air per second were passing out of the works in this direction;* a quantity totally inadequate to the safe ventila-

*. Mr. Dunn says, that the least quantity of air required in a fiery colliery is from 350 cubic feet to 400 cubic feet per second.

tion of a colliery producing so much fire-damp; for it must be remembered, that the whole of the air entering the colliery is made to pass through this air-way, after having travelled through the works, and therefore shows the whole quantity used in ventilating it.

The headways and stalls bore evident traces of the late explosion, the sides and roof having a coating of soot and fine dust like the inside of the chimney of a large furnace, and many of the props and transverse bearers of the roof were charred by the fire.

4°. The facts previously stated, as to the large quantities of fire-damp produced,—the imperfect means of ventilation pursued, and the deficient quantity of fresh air supplied,—the fiery state the colliery was in for three, or four days before the accident happened, —the carelessness shown in the use of the safety-lamps, and that two were found with the gauze cylinders off, after the explosion had occurred,—are unequivocally indicative of the causes of the explosion, and conclusively prove, that primarily, it was owing to the imperfect ventilation of the mine, and secondly, to the neglect of not enforcing proper care in the use of the safety-lamp. Yet after an investigation which occupied five days, in which all these facts were proved, the coroner's jury returned a verdict of "Accidental death."

The circumstance of there being no fire-damp observable whilst the Inspectors were in the mine, may be attributed to the explosion having entirely cleared the mine, and no damp having been generated, as no coal had been worked during the fortnight that ensued before the inspection. There did not appear to be any regular and constant blowers of gas, but it was evolved in large quantities on cutting, or hewing the coal. The pulverised state, in which the greatest proportion of the coal is obtained, renders the disengagement of the gas more rapid and complete than if the produce were principally large coals. This is proved by an experiment made by Sir Humphry Davy, who, on breaking some large coal under water, collected a quantity of fire-damp on the surface of the water which had escaped from the coal on being broken small.

5°. An examination of the accompanying plan will show, that there are no insuperable obstacles to the adoption of the ordinary means for obtaining the good ventilation of this colliery. This object would be effected, by enlarging the small air-ways, the erection of a proper furnace, and constantly using it,—the division of the air into several columns,—the sufficient ventilation of the 'deads,' or abandoned works,—and the construction of the requisite doors, stoppings, and crossings in a substantial manner, which are all easily practicable at no extraordinary expense.

With the improved ventilation of the mine, proper regulations with respect to the safety-lamp ought to be instituted and be strictly enforced.

Experience has shown the great utility of these measures in preventing similar accidents; and, although it is to be regretted, that more certain remedies are yet unknown, or not proved, no doubt can be entertained, that had these means been skilfully employed, in this instance, the lamentable explosion would not have occurred.

It is but justice to the owners of this colliery to state, that they have shown a very laudable desire, both on a former as well as on the present occasion, to improve the ventilation of the mine; that they expended about £500 for that purpose in 1845, and are now erecting Mr. W. P. Struvé's new mine-ventilator,* which is estimated to cost £400. By this machine, Mr. Struvé states he can pass 40,000 cubic feet of air through the mine in a minute, or 666 cubic feet per second: the present quantity passing through the mine is, at most, not more than 53 cubic feet per second. All remarks upon this, or any other attempted improvements in progress would be premature, the subject will be therefore reserved until the scheme has been fairly tried; and if it is proved to be a decided improvement on the present system of mine ventilation, which is pursued, not because it is perfect, but because a better system is unknown, the talented inventor will deserve the gratitude of all concerned in mining operations.

The Paper is illustrated by a working plan of the colliery, (No. 4,366,) from which Plate 5 is compiled.

Mr. Warington Smyth concurred in most of the remarks made in the Paper, but at the same time he doubted whether the systems of mining and of ventilation adopted in the North would be found perfectly applicable to the South Wales coal-field. For instance, it might, he thought, be found preferable, instead of ventilating the exhausted parts of the workings, to allow the roof to fall, so that no 'goaf,' or empty space should be left, and the dangerous consequences of a magazine of inflammable gases would be thus altogether avoided.

He believed, that Mr. W. P. Struvé's new ventilator was likely to be useful; but he thought if the old system of furnace ventilation,

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* An account of this mode of ventilation, and its subsequent employment at the Eaglesbush Colliery, is given in a Paper by Mr. Struvé, read before the Institution, November 19, 1850. *Vide* vol. x. p. 22.—Editor.

used in good mines in all countries, had been properly applied in the case under consideration, there would not have been any necessity for a mechanical moving of the air, nor, in fact, would there have been any explosion to record. The air-courses ought to have been larger, to have enabled the furnace to have passed through it the requisite quantity of air for so large a mine, and it should have been constantly worked. Mechanical ventilators of somewhat similar construction to that proposed by Mr. Struvé had been tried in Belgium, for many years, with some success. At the mine called L'Espérance, in Belgium, there was one of those machines, worked by an engine of 25 H.P., which passed between 30,000 and 40,000 cubic feet of air per minute. The Belgian Engineers, however, complained, that there was great loss of power, for as the great desideratum in ventilating a colliery was to impart a low velocity to large masses of air, there were mechanical difficulties in effecting this by a machine, by which the air had to be passed through a comparatively small valve, thereby giving considerable velocity for the time, and the friction consequent upon it produced such a loss, that they had almost arrived at the conclusion of other and simpler means of ventilation being preferable.

There were also advocates for the use of fans, both for forcing the air into and exhausting it from the air-courses. The old system of the furnace at the upcast shaft was, perhaps, after all, the cheapest and the simplest of all contrivances for the purpose, the small coal, often treated in the mine as rubbish, being all that was required for giving the exhausting power, and the furnace was, certainly, less liable to get out of order.

Another system of rarefying the air was by the steam jet, proposed by Mr. Gurney, which he had no doubt was occasionally capable of application. Very few of the collieries in England could afford to have a shaft solely devoted to the upcast air, and where the jet was passed into the shaft, great inconvenience was occasioned to the men who were raising the coal to the surface. This system had been lately introduced in the North with some success, and he thought it was capable of extended application.

In the case of the Eaglesbush and other similar collieries, the establishing a current of air was not the only desirable object; the principal point, and one which depended entirely on the experience of the mining agent, was the proper distribution of the air in the workings under ground, and the manner in which the general plan was laid out at the commencement.

There were many methods of working coal, from the broad way in which it was worked in Shropshire, to the plan in use in the

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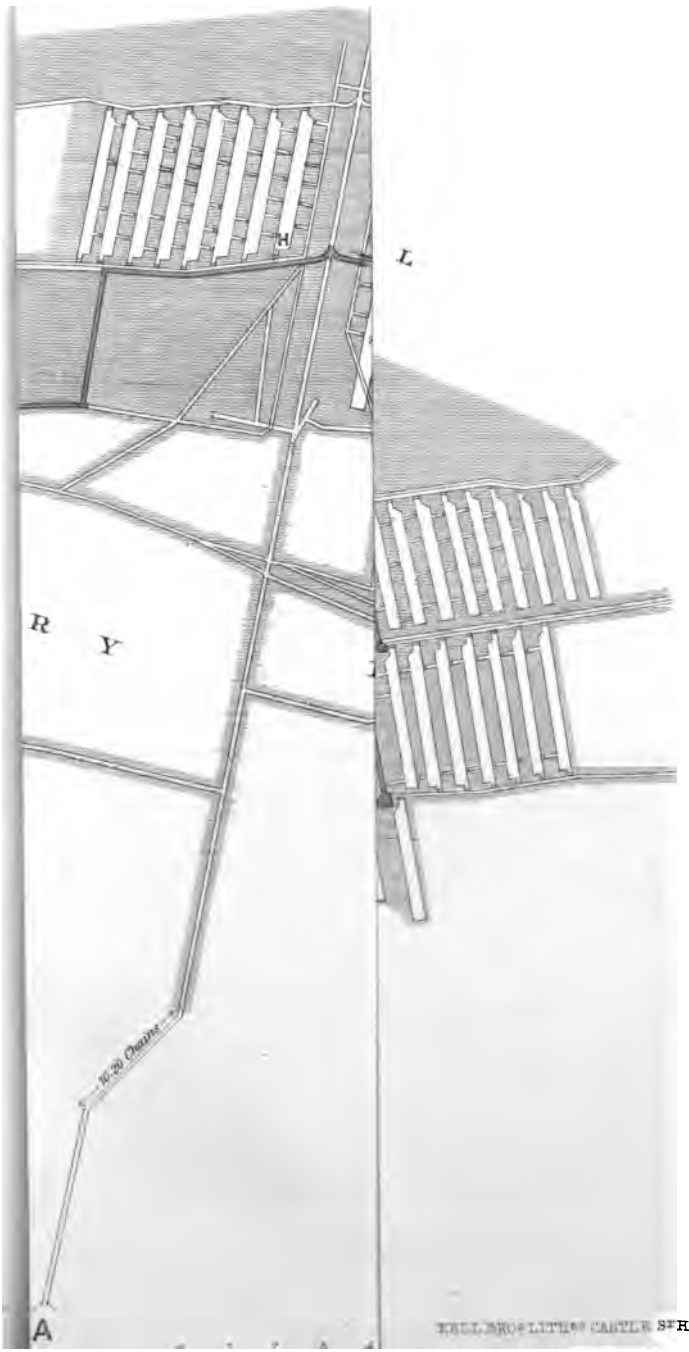
PLATE 5.



HELLER & LITH^RS CASTLE ST HOLBORN.

North, where narrow passages were driven, leaving strong pillars of coal, which were subsequently removed; it therefore required great experience to lay out a colliery in the best mode, and on the method of working must depend the system of circulating the air through the mine. Mr. Nicholas Wood and the late Mr. George Stephenson had, at a former Meeting of the Institution,* made some valuable remarks on the collieries of which they had the inspection in the North, and there was no doubt, that under the superintendence of such men, all that science, or skill could do would be applied to render the ventilation perfect; but, unhappily, those few collieries formed only the exception. Approaching the West, there were numerous collieries in which not only was there little, or no attention paid to ventilation, but where the system of working was miserably bad in every way, and was so wasteful of the coal in the ground as to amount to a cause for national regret. In such cases the only prospect of improvement was by inducing increased intelligence in the overmen, and giving the agents the opportunity of becoming acquainted with works conducted on a better principle. If such men as Mr. Wood, or Mr. Stephenson, could point out to those persons the manner in which their collieries were conducted, they would, doubtless, be happy to adopt it, but many of them were even unable to read, or write, and were naturally ignorant of the systems in use in other places.

In passing through the air-courses in some of these collieries, he had actually not been able to discover which way the air was travelling, and yet he was told it was perfectly good air. The miners considered the ventilation to be sufficient, because, under ordinary circumstances, there might be no immediate danger; but if there was a change of temperature, or if a fall of the roof suddenly occurred, the gas would be driven out, to the parts where the men were working, perhaps with open candles, and the result would be an explosion. Now in most of the collieries of the North, the usual quantity of air passing regularly through the workings, was not less than 50,000 cubic feet per minute.

In these accidents, there were two principal causes leading to the explosion: the first arising from the manner of working and of ventilation, and the second from the ignorance and recklessness of the men, and falling under the head of discipline. In the Eaglesbush Colliery, the men were obliged to supply their own safety-lamps, instead of their being furnished by the management; it was very probable, therefore, that an ignorant and poor collier should

* *Vide* Minutes of Proceedings, Inst. C.E., 1847, vol. vi., p. 186, *et seq.*

even prefer to work in a dangerous atmosphere, using a candle which gave a better light, rather than incur the expense of a lamp, which did not enable him to cut so much coal. In the North, the weary colliers, on leaving their work, gave up their lamps to a person whose sole duty it was to clean, examine, and trim them, and return them securely locked to the men on descending to their labour. It was found, that unless that system was adopted, the men constantly brought their lamps in such a condition, that the gauze would allow the flame to pass through. Again, it was necessary continually to cut slits from one stall to another, through which the current of air might pass: this ought to be done by, and under the direction of the manager, so as to properly regulate the distance between these through-cuts, but it was frequently left to the men: consequently, if the poor fellows were in want of a few shillings, they would rather push on in danger, than stop to make the through-cut upon which their safety depended.

Mr. Smyth then adverted to the necessity for enlarging the air-courses in such collieries. If an upcast and a downcast shaft were connected by a horizontal passage of inadequate area, it was evident, that the quantity of air they passed must necessarily become stagnant in the narrow passage, unless great propelling and exhausting force was employed. In Staffordshire, the air-courses were frequently confined to 3 feet, or 4 feet by about 14 inches; consequently, the whole volume of air circulating through the colliery was gradually stopped, and must become stagnant after arriving at such a throttle-valve.

The upcast shaft, to which Mr. Richardson had referred, was much mismanaged; the culvert was carried up the side of a hill, but, in consequence of the furnace not having been kept alight at the bottom of the chimney, the air was cooled down in its passage from the mine, instead of obtaining an increased degree of heat, which might have augmented its velocity along the shaft. The danger of this was evident, for on examination it was found, that the difference between the external and internal air was not more than 8°. On the morning of the explosion, the sun shone, at ten, or eleven o'clock, with great warmth; the thermometer rose considerably, so that in a short time the temperature of the external air must have risen higher than that of the internal air; consequently, there was an immediate tendency to reverse the action of the downcast and the upcast shafts, and the consequence was a total stagnation of the ventilation. Then probably the gas issuing from fresh-cut coal came in contact with the open candles, and produced the melancholy result which had been described.

In conclusion, he begged to direct attention to the necessity which existed of improving the moral and intellectual condition of the colliers, and particularly of the underground agents, on whom so much depended. In Belgium, since an inspection had been established, and the latest improvements in ventilation, of the last five, or six years, had been introduced, the quantity of coal cut had increased nearly 20 per cent., the number of workmen employed had increased 17 per cent., and the number of accidents had diminished 25 per cent.; if equally correct statistics on this subject could be obtained in England, he feared the result would be found to be different. He had lately inspected a colliery in Yorkshire after a similar accident, and had been confirmed in his opinion, of greater attention being paid to the ventilation there, than in the western districts.

The Welsh coal-field principally demanded attention, as it was from thence that the great supply of coal must eventually be procured, when that from many of the present coal-fields should cease, which would be at no distant date. Unhappily in that district there was, at present, the greatest amount of want of practical skill and of theoretical knowledge, and almost irremediable injury might be done to the coal-fields, by opening the mines improperly.

Mr. GLYNN thought the last speaker had been unfortunate in selecting a corner of England where so much ignorance prevailed on the subject of mining, and he also thought the miners of this country would scarcely be induced to work under the same kind of Government superintendence as in France and Belgium, and that there was sufficient intelligence in the body of Civil Engineers, to direct collieries effectually, and with due care, without submitting to such interference as that with which the Corps d'Ingénieurs des Mines had the power of offering.

In the Midland districts, great attention was paid to the ventilation of the pits, in having the downcast and upcast shafts of sufficient area, and the connecting courses of adequate dimensions and well directed; and in order to ascertain by simple means whether the system always worked well, Mr. Biram, who had the superintendence of some of Earl Fitzwilliam's collieries, had invented a very useful anemometer for ascertaining the velocity, and thence the volume of the current of air travelling through the mine. The practice there was to leave the working passage only; to get nearly the whole of the coal, and to allow the roof to fall; then by keeping the air-courses free, and whenever there was reason to apprehend an escape of gas, providing the men with safety-lamps, nearly all danger was avoided. Now when the system was so clear, Mr. Glynn must contend, that it was unnecessary to have the superin-

tendence of a Government board, of which kind of supervision he thought there had been already attempts to establish too much, and he should be sorry to see any further steps adopted in the same direction.

Mr. TAYLOR believed, that Mr. Smyth did not mean to argue in favour of direct Government interference, but thought it desirable to have the miners properly educated, and the best system of ventilation being decided upon, its adoption should be enforced in all those mines where, at present, too much ignorance prevailed. Mr. Glynn must be aware, that there were many collieries in which the best methods were neither understood, nor even attempted, and the tendency of Mr. Smyth's remarks was to show that, as there was a nearly perfect mode of ventilation, the knowledge of the existence of that mode ought to be extended into districts where it was not now understood.

Mr. GLYNN replied, that he did not mean to reflect on what had been said, regarding the actual system of ventilation of mines, as it was substantially correct; but he knew there had been, from time to time, endeavours to enforce a Government superintendence. Now with such men as Mr. N. Wood in the North, and Mr. Taylor in the West, he could not but think, that not only was such superintendence unnecessary, but that it would even be prejudicial.

Mr. BRUNEL observed, that whilst he fully approved the sentiments of Mr. Glynn, with respect to the present desire to introduce Government interference into all public undertakings of magnitude, he was bound to say he did not at all understand Mr. Smyth as suggesting, or recommending that sort of Government interference which should limit the responsibility of the actual managers. At the same time, he could not lose the opportunity of expressing the strong objection which, it was well known, he entertained of Government interference of any kind, as its effect must be to lay down inflexible rules as to what was to be considered good, and thereby to prevent improvement.

Mr. WARINGTON SMYTH explained, that he intended merely to direct attention to the advantages that must result from the improvements of well-regulated collieries being carried to districts where such works were at present ill-managed; and in this he felt sure of sympathy, as it must be admitted to be a rational means of preventing the sacrifice of human life which too frequently occurred at present. He, however, agreed, that it was not by any Government interference, alone, that this could be carried out; in fact, he would strongly deprecate any Government interference, by which the responsibility should be taken from the present managers of mines,

to be thrown on persons who, however scientific, or even experienced in mining, could not be on the spot, and would not know the circumstances of the case.

Mr. GLYNN stated, that Mr. Matthias Dunn, colliery viewer of Newcastle-upon-Tyne, whose experience in the working and ventilation of coal-mines was well known, had recently published a work "On the Winning and Working of Collieries," including remarks on ventilation, in which he said:—

"In order suitably to conduct the operations of a mine, a good system of ventilation is imperative, which consists in the conveyance of a succession of atmospheric air through the workings, which must be sufficiently powerful not only to enable the people to respire freely, but also to detect and carry off the continual product of carburetted hydrogen, or carbonic acid gases, which are inseparable from the working of mines.

"For a series of years this subject has been the continued theme of newspaper controversies and theoretic disquisitions, and it has also been discussed in Parliament, whenever the public mind has been roused to sympathy by sudden explosions accompanied with loss of life. The merits of the different systems of ventilation, it is, therefore, my intention to bring under notice; but I will first proceed to show the origin and progress, as well as the amount of perfection, to which present practice has attained in different parts of the kingdom.

"The basis of ventilation consists of a spacious upcast and downcast shaft, with adequate air-courses under ground; but as the air will not, of its own accord, continue steadily to ascend the upcast shaft, the current must be carried by some artificial means.

"The most simple, and up to the present moment I may say, the most practically efficient plan, is rarefaction, namely, the placing contiguous to the bottom of the upcast shaft a lamp, or furnace, to be constantly kept burning, and whose natural effect, both upon the air-current and upon the shaft, is to produce an acceleration of the air, corresponding with the space of the air-courses and the magnitude of the furnace, and this is by rarefaction of the air.

"In very early times, a tube, or high chimney, was built contiguous to the top of the upcast shaft, into which tube a fire, or furnace was occasionally introduced; but experience showed, that it was more efficacious when applied to the shaft itself.

"Objections to this application have been found, inasmuch as, when the return air becomes vitiated with inflammable gas to a dangerous amount, frequent instances have occurred of the said air exploding at the flame of the furnace.

"To obviate this objection, it is customary to feed the furnace with fresh and uncontaminated air, whilst a separate passage, called a dumb drift, is provided for the general return air of the pit, which passes into the shaft at an outlet considerably superior to that of the furnace air."

M. Perdonnet, Ingénieur des Mines, in his treatise, "De l'Histoire et de la Nature de la Propriété Souterraine," said:—"Au gouvernement seul les vues d'avenir, et la possibilité d'embrasser tous les intérêts particuliers, dans leur rapports avec l'intérêt général; à lui par conséquent, le pouvoir d'agir comme le réprésentant de la majorité éclairée, pour le bien du pays; si vous le croyez incapable, ou corrompu, renversez-le, changez-le, mais ne contestez pas le principe."

Mr. FAREY was of opinion that, taking into account the great increase in the production of coal, the number of accidents had, of late years, proportionately diminished.

Mr. R. STEPHENSON, M.P., *V.P.*, said the number of accidents had diminished in England, as compared with those in Belgium, under the same circumstances. In Great Britain, the quantity of coal gained per annum had increased, within the last twenty years, from about eight millions of tons to sixteen, or seventeen millions, (more than double,) and he believed, that the loss of human life had been, on the whole, less; but there was the remarkable circumstance, that the accidents which occurred, at the present time, were generally more serious. It must also be borne in mind, that mines were, at present, worked for coal, which could not, twenty years ago, have been worked safely, or indeed, at all. New material, and double the former quantity of raw material, were, therefore, now raised, with a less consumption of human life than formerly. Whatever might be the recent improvements in Belgium, equally serious accidents occurred in that country, without its producing the same quantity of coal as England.

With respect to ventilation, it might appear almost rash to assert, that it had arrived at perfection, yet he really believed, that it scarcely admitted of improvement. The application of a rarefied column of air in the upcast shaft of a coal-pit was so simple, that if the interior workings were kept in good order, it was almost impossible, that any accumulation of gas could take place; but safety did not merely depend upon the ventilation, which was easy of command. In an ordinary mine, the air, in performing the circuit of the mine, frequently had to pass through twenty, thirty, or forty miles of channel in the bowels of the earth, and safety depended, not only on those channels being kept in good order, but on a number of

doors being kept open, or shut, at particular times, for driving it in particular directions; and when it was remembered, that all these operations must be confided to human agency, it was only surprising how few accidents took place. Mr. Smyth had observed that, previous to the recent accident at Barnsley, the temperature of the external air was much elevated, and the ventilation was, consequently, sluggish. Mr. Stephenson, however, did not think, that any change of temperature of the air would at all affect the ventilation of the mine, which depended on the temperature of two volumes of air, distinct from the atmosphere. But one circumstance connected with the atmosphere, which did really seem to affect the ventilation of a mine, was the fall of the barometer. Almost every serious accident within the last twenty-five years, had taken place immediately after a very marked fall of the barometer. This, he thought, might be thus accounted for: in coal, under the ordinary atmospheric pressure, a large quantity of carburetted hydrogen gas was in a state of equilibrium, or in a fluid state; but when that pressure diminished, the fluids passed into the gaseous state. If, then, the admixture of pure air with the foul air had been nearly approaching to the point of expansion, the fall of the barometer would necessarily increase the quantity of the latter, and give rise to accidents such as that at Barnsley.

Government interference, in mining operations, was an important question. He thought it was utterly impossible, for any person, not continually on the spot, to attempt to lay down strict rules for regulating a mine, as the conditions were constantly changing. It might become necessary, for example, to alter the mode of ventilation on a Sunday morning, which he had been compelled to do repeatedly, when least expected; perhaps a fall had taken place and the air had to be carried in another direction, and it entirely depended on the miner's judgment, whether a good, or bad plan was adopted. He believed that, generally speaking, the collieries in the North were carefully attended to, and the existence of a badly conducted establishment, elsewhere, ought not to be held sufficient to justify Government interference with the whole. The management of collieries, although simple in practice, was complicated in principle, and could not be regulated by theoretical rules laid down by Government.

Mr. C. Manby, Secretary, stated that, as had been suggested, he had communicated with Mr. Biram, of Wentworth House, and had, through his intervention, received from Mr. Davis, optician, of Derby, one of the anemometers made by him for mining purposes, on the plan invented by Mr. Biram, from whose letter he then read

the following extracts:—"I have gratifying reports of the utility of my anemometer from several parties who have tried it; but more particularly from Mr. Woodhouse, of Overseal, Ashby-de-la-Zouch. He regularly registered the current of air passing through the numerous mines under his charge, noting also the height of the barometer, and is deeply impressed with the importance of such observations.

"I think it very desirable, that some improved system should be pursued for ascertaining the volume of air passing through the mines in various parts of the country, and can, with confidence, recommend this instrument, as calculated to give such uniformity. The smallness of its price should be a further inducement for its use. If it err, it will be on the safe side, by registering less than the true velocity of the current. The velocity of the current per minute, will, of course, require multiplying by the area of the passage in which the instrument is placed, to arrive at the number of cubic feet of air passing in any given time.

"It appears to me, that the aneroid barometer would be an excellent accompaniment to this, or some better instrument for the same purpose, and should be in the hands of every person having the charge of the ventilation of mines; and that a daily register should be kept of the pressure and velocity of the air in all mines, at least, which generate carburetted hydrogen gas."

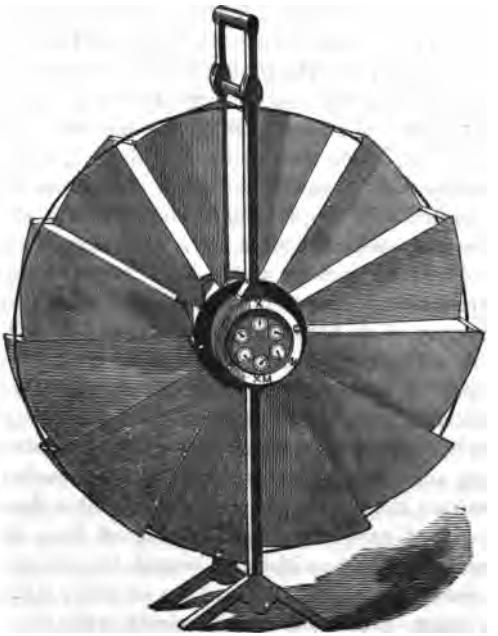
The anemometer exhibited* was a very simple instrument, consisting of a wind-wheel, having very light vanes, or sails, so formed, that the action of the wind upon every part of them, tended to produce one revolution of the wheel in the same time that the wind travelled 2 feet. On the axle of the wind-wheel was a worm, or endless screw, into which worked a wheel with fifty teeth, every revolution of which, therefore, indicated the passage of a current of 100 feet of air. The toothed wheel was subdivided into 10 equal parts; so that an observer, noticing the number of revolutions and parts made by it per minute, would perceive the velocity of the current, in feet per minute, at the time of observation.

To facilitate the observation, a minute-glass should be used, which should be turned after the lapse of a few seconds, or as soon as the wheel had acquired a uniform velocity. By dividing the velocity in feet, thus found, by 88, (the $\frac{1}{60}$th part of a mile,) the velocity in English miles per hour was given.

For registering the current of air for a length of time, the instrument was mounted on a frame, and connected with wheel-work

* Manufactured by Mr. John Davis, Optician, Derby.

Fig. 1.



Biram's Anemometer.

which gave motion to six indices; the first circle making one-tenth of a revolution for 1,000, the next for 10,000, and the others, proportional advances for the number of feet of air passing through the wind-wheel. When in use, so often as 1,000,000 feet were indicated by the wheel, the indices would all stand at Zero, or X, upon the different circles; but it was not necessary, that they should be so placed upon the anemometer, on its first being fixed in any situation, provided the position of the indices at the time was carefully observed. Upon making a second observation, the position of the indices should be noticed, (adding ten to the number indicated by the Cs. of Ms. circle, if the index had, in the interval, passed X, or Zero,) and by deducting the amount of the first observation from the last, the difference would be the number of feet of air which had passed through the wheel between the two observations.

Mr. Biram had also introduced a new Miner's Lamp, which consisted of a metallic casing, enclosing the lamp on all sides except in front, the inside forming a reflector. The height of the wick in the oil vessel was regulated by a rack and pinion, the axis of the pinion

fitting into a key in the back of the casing, which was turned by a button, or stud, at the outside. A strong-jointed wire was also fitted into the back of the casing, level with the top of the wick tube, and bent at the inner end, at right angles, for the purpose of occasionally pushing off the carbonized matter from the top of the wick, which, however, with good oil, would seldom be required. The door of the lamp, in front, which was flanched at the top, fitted accurately into grooves prepared on each side, and in the bottom of the casing; and being locked with a spring-catch into the top of the casing, could not be reopened without a key. The chimney of the lamp was provided with an opening at the back, in which was inserted a piece of wire-gauze, and over it was a loose top, so contrived as to prevent a current of air blowing down the chimney, and extinguishing the light. The front part of the door for emitting light, might be made either of wire-gauze, or talc; if of talc, the air for supporting combustion could be admitted through wire-gauze at the bottom. When this lamp was placed in an inflammable atmosphere, the air, being admitted through the door only, immediately ignited, and burnt within the wire-gauze with a slight blue flame. As any further supply of oxygen was thereby cut off from the wick, the light, unless immediately withdrawn, would be extinguished, with no other inconvenience to the bearer than his being left in the dark; and as he must necessarily communicate with the person who carried the key, before his lamp could be relighted, the fact of any part of the workings being foul could not occur, without its necessarily coming to the knowledge of those in authority. Thus whilst the lamp protected the miner against any sudden influx of gas, it also required, that the general ventilation of the mine should be below the explosive point, to enable the men to work. At the same time, provision could be made for occasional working in fiery parts of a mine, by having an elastic flexible tube screwed over the orifices in the door, the other end of the tube being conveyed into pure air.

With regard to light and economy, the result of some comparative experiments fully proved, that with the same wire-gauze door of the same mesh as the common Davy lamp, the light was four times greater, and with a talc door, about sixteen times as great, or four times that of a naked candle. These results were arrived at by fixing a wax candle, (of four to the lb.,) as a standard, at one yard distance from a screen of white paper,—and the light to be compared with it, at such a distance, that the shadows falling from an object placed between the two lights and the screen should be of equal intensity; the square of that distance being

taken as the degree of light due to the different luminaries. The consumption of tallow, or oil, was ascertained by weighing the candles and oil vessels before lighting, and after they had been burning for a certain period, the difference showing the consumption during the time of combustion.

——	Distance from the Screen.	Degree of Light.	Decrease in Weight per hour in grains.	Costs per hour in parts of a penny.
				d.
Wax Candles	1·0	1·0	117	..
Davy Lamp	0·53	0·28	90	·0428
Biram's Lamp,* with gauze door .	1·03	1·06	90	·0428
„ „ with talc door . .	2·	4·00	90	·0428
Common Pit Candle,† (fresh snuffed), burning free from draft	0·85	0·72	118	·101
Ditto ditto .	0·9	0·81		
In practice, a Candle was found to give	..	..	145	·125

* Whale Oil, 2*s.* 6*d.* per gallon. † Candles, at 6*d.* per lb.

Compared with the Davy lamp, this lamp gave with a wire-gauze door four times the light, at the same cost; and compared with a candle as much light, at one-third the cost.

Attention was also directed to some specimens of the Aneroid Barometer, sent by Mr. E. J. Dent, (Assoc. Inst. C.E.). This instrument, which it was supposed by Mr. Biram should be used in conjunction with his anemometer, was of somewhat recent importation into this country, and on account of its sensitive action, its portable form, and its moderate price, was being generally used for observations. The chief novelty consisted in the employment of a vacuum-vase, instead of the column of mercury, or any other fluid.

February 27, 1849.

JOSHUA FIELD, President, in the Chair.

No. 767.—"On Fire-proof Buildings."* By James Braidwood, Assoc. Inst. C.E.

THE defects in the construction of fire-proof buildings have been already brought before the Institution, in a Paper by Mr. Wm. Fairbairn, M. Inst. C.E., read on the 20th April, 1847,† the Author,

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* The discussion upon this Paper extended over portions of three evenings, but an abstract of the whole is given consecutively.

† *Vide* Minutes of Proceedings Inst. C.E. 1847, vol. vi., p. 213.

however, would again direct attention to the subject, under the impression, that the matter was then considered, principally with regard to the strength and position of the materials necessary to support a given weight, without adverting sufficiently to the effect which fire has upon them, and especially upon iron, which is the material now almost universally employed for supporting the different parts of such structures. The information elicited in the discussion upon that Paper was, doubtless, of the highest importance with respect to constructions for the support of railways, &c., which are not liable to any higher temperature, than that of the atmosphere; but with regard to fire-proof buildings of considerable extent, where combustible goods may be stored, and where, in case of fire, the temperature will be very high, the question assumes a totally different aspect.

The Author has repeatedly observed cast and wrought iron to be fused, at fires in large buildings, such as warehouses, sugar-houses, &c.; the following specimens, (laid on the table,) prove the fact:—

No. 1. Various parts of arms, from the fire in the Armoury at the Tower, on the 30th October, 1841.

No. 2. A piece of steam-pipe, 5 inches in diameter, from Messrs. Grant's sugar-house, London, 22nd February, 1846.

No. 3. A piece of burnt wrought-iron trial tube.

No. 4. A piece of a cast-iron pillar, from Mr. Macfie's sugar-house, Liverpool, 1846.

No. 5. Various pieces of cast iron from the warehouse on Irongate Wharf, London, 31st December, 1846.

From these specimens it is evident, that the temperature in large buildings on fire, is occasionally equal to the fusing-point of cast-iron. According, however, to Mr. Fairbairn's experiments on cast iron, in a heated state, it is not necessary that the fusing-point should be attained, to cause it to give way.* He also states, that the loss of strength in cold-blast cast iron, in a variation of temperature from 26° to 190° = 164° Fahr., is 10 per cent., and in hot-blast at a variation of from 21° to 190° = 169° Fahr., is 15 per cent.; now if the loss of strength advances in anything like this ratio, the iron will be totally useless, as a support, long before the fusing-point is attained.

Much confidence has been placed in wrought-iron tie, or tension rods, to take the lateral strain of the arches, and also in trusses to

* *Vide* "Seventh Report of the British Association, 1837," vol. vi., p. 409.

support the beams; but it must be evident, that the expansion of the iron from the heat would render them useless, and under a high temperature, it would be so great as to unsettle the brick-work, and to accelerate its fall, on any part of the iron-work giving way: again, the application of cold water to the heated iron, in an endeavour to extinguish the fire, is almost certain to cause one, or more fractures. The brick-arching is also very liable to fall, especially if only 4½ inches thick, independently of the weight which may be placed upon it, for it is not uncommon, after a fire in a large building, to find the mortar almost completely pulverized, to the depth of 3 inches, or 4 inches from the face of the wall. When a fire occurred under one of the arches of the Blackwall Railway, on the 15th July, 1843, a portion of the lower ring fell down, and also a few bricks from the next ring.

Another very serious objection to buildings of this description, is that, unless scientifically constructed, they are very unlikely to be safe, even for the common purposes intended, independent of the risk of fire. In the Report of Sir Henry De la Bèche, and Mr. Thomas Cubitt, on the fall of the mill at Oldham, in October, 1844,* it is stated, that the strength of the iron beams was within 10 per cent. of the breaking weight. Now according to Mr. Fairbairn's experiments on heated iron, already referred to, an increase of temperature of only 170°, would have destroyed the whole building. It is quite clear, therefore, that so long as mill-owners and others continue to construct such buildings without proper advice, they must be liable to these accidents. In timber floors there can be no such risk, as the strains are all direct, and any journeyman carpenter, by following good examples, can ascertain the size required; and even if he makes a mistake, the evil is comparatively trivial, as the timber will give notice before yielding, and may be propped up for the time, until it can be properly secured. In the case of fire-proof buildings, an ignorant person may make many mistakes, without being aware that he has done so, and the slightest failure is probably fatal to every one within the walls. This also increases the difficulty and danger of extinguishing fires in a large building, as the only method of doing so, is for the firemen to enter it with their branches, and in case of the floors falling, there is no chance of escape. On the other hand, timber floors have repeatedly fallen while the firemen were inside the building, and they have made their escape uninjured.

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* *Vide* "Report on the Fall of the Cotton Mill at Oldham, and part of the Prison at Northleach," page 4. Folio. London: Clowes and Sons, 1845.

In a pamphlet published by Mr. S. Holme of Liverpool, in 1844,* and which contains a report from Mr. Fairbairn on fire-proof buildings, it is stated, that many people, especially in the manufacturing districts, are their own architects; that the warehouses in Liverpool may be loaded to one ton per yard of flooring; and that unless great care and knowledge are used in the construction of fire-proof buildings, they are of all others the most dangerous.†

The following are the principles on which Mr. Fairbairn proposes to build fire-proof warehouses:—

The whole of the building to be composed of non-combustible materials, such as iron, stone, or bricks.

In order to prevent fire, whether arising from accident, or spontaneous combustion, every opening, or crevice, communicating with the external atmosphere to be closed.

An isolated staircase, of stone, or iron, well protected on every side by brick or stone walls, to be attached to every story, and be furnished with a line of water-pipes, communicating with the mains in the street, and ascending to the top of the building.

In a range of stores, the different warehouses to be divided by strong partition walls, in no case less than 18 inches thick, and no more openings to be made, than are absolutely necessary for the admission of goods and light.

That the iron columns, beams, and brick arches be of sufficient strength, not only to support a continuous dead pressure, but to resist the force of impact, to which they are subject by the falling of heavy goods upon the floors.

That in order to prevent accident, from the columns being melted by intense heat, in the event of fire in any of the rooms, a current of cold air should be introduced into the hollow of the columns from an arched tunnel under the floors.

There is no doubt, that if the second principle could be carried out, namely, the total exclusion of air, the fire would go out of itself; but it seems, to say the least of it, very doubtful indeed, if this can be accomplished, and, if it could, the carelessness of a

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* *Vide* "Report of W. Fairbairn, Esq., on the Construction of Fire-proof Buildings. With introductory Remarks by Samuel Holme," page 11, *et seq.* Tract, 8vo. Liverpool: T. Baines, 1844.

† The Author has been informed by Mr. Farey, (M. Inst. C.E.,) that a fire took place, in 1827, in a mill belonging to Mr. Marshall, of Leeds, the whole of which, with the exception of the roof, was fire-proof. The upper floor was filled with flax, which took fire; the roof fell in, and the heat so affected the iron beams of the floor, as to cause them to give way.

porter leaving open one of the doors, or windows, would make the whole useless. The fifth principle shows, that Mr. Fairbairn has omitted to allow for the loss of strength the iron may sustain, from the increase of temperature. The last principle would not be likely to answer its purpose, even if it was possible to keep these tunnels and hollow columns clear for a number of years, which is scarcely to be expected. A specimen of iron pipe, 1½ inch in diameter, was heated for four minutes in a common forge, both ends being carefully kept open to the atmosphere, when, on one end being fixed in a vice, and the other pulled aside by the hand, it gave way.

One of the principal objections to the kind of fire-proof buildings above described, is, that absolute perfection in their construction, is indispensable to their safety; whereas buildings of a more common description are comparatively safe, although there may be some errors, or omissions in their construction. Indeed, Mr. Fairbairn states, in the same Report, that, "it is true that negligence of construction, on the one hand, and want of care in management, on the other, might entail risk and loss to an enormous extent."

For the reasons here stated, the Author submits that large buildings, containing considerable quantities of combustible goods, with floors of brick arches, supported by cast-iron beams and columns, are not, practically speaking, fire-proof; and that the only construction which would render large buildings fire-proof, where considerable quantities of combustible goods are deposited, would be groined brick arches, supported by pillars of the same material, laid in proper cement. The Author is fully convinced, from upwards of twenty-two years' experience, that the intensity of a fire,—the risk of its ravages extending to adjoining premises,—and also the difficulty of extinguishing it, depend, *cæteris paribus*, on the cubic contents of the building which takes fire, and it appears to him, that the amount of loss would be very much reduced, if, instead of building immense warehouses, which give the fire a fortified position, warehouses were made of a moderate size, with access on two sides at least, completely separated from each other by party walls, and protected by iron doors and window-shutters. In the latter case, the probability is, that not more than one warehouse would be lost at a time, and perhaps that one would be only partially injured.

The Paper is illustrated by specimens showing the effect of various degrees of temperature upon wrought and cast iron.

Appendix.

Since the foregoing Paper was written, the Author has seen what he esteems a very clear proof of the inability of cast iron to resist the effects of fire.

A chapel in Liverpool-road, Islington, 70 feet in length and 52 feet in breadth, took fire in the cellar, on the 2nd October, 1848, and was completely burned down. After the fire, it was ascertained, that of thirteen cast-iron pillars used to support the galleries, only two remained perfect; the greater part of the others were broken into small pieces, the metal appearing to have lost all power of cohesion, and some parts were melted, of which specimens are now shown. It should be observed, that these pillars were of ample strength to support the galleries when filled by the congregation; but when the fire reached them, they crumbled under the weight of the timber only, lightened as it must have been by the progress of the fire.

In this case it mattered little whether the pillars stood, or fell; but it would be very different with some of the large wholesale warehouses in the City, where numbers of young men sleep in the upper floors: in several of those warehouses the cast-iron pillars have less strength in proportion to the weight to be carried than those referred to, and would be completely in the draught of a fire. If a fire should unfortunately take place under such circumstances, the loss of human life might be very great, as the chance of fifty, eighty, or one hundred people escaping, in the confusion of a sudden night alarm, by one, or two ladders to the roof, could scarcely be calculated on, and the time such escape must necessarily occupy, independent of all chance of accidents, would be considerable.

Professor Hosking testified to the accuracy, with which Mr. Braidwood had treated the facts which had come under his observation. He had carefully examined the results of many of the great fires in London, within the last few years, and had observed the general insecurity of buildings, depending on either cast, or wrought-iron, in cases of fire occurring. It was not for him to offer even suggestions, as to what might be adopted, to prevent the consequences of fires; the interference of public authorities should not be allowed to control the discretion of private individuals, except when their acts were calculated to be injurious to the public welfare. He believed much evil had already resulted from injudicious interference, and he fully concurred in the opinion, that none but those who were practically concerned in works, could know where the weak points were, or how to remedy them. He was every day more sensible of his incompetence to deal with the works of others; those who had studied the designs and watched the progress of works, might speculate with some accuracy on the probable result; but those who only examined them after an accident of any kind, could only speculate on contingencies. He had that day examined a work, executed by one of the most competent contractors in London, of which, considered abstractedly as a structure, he would not certify

he safety, because of circumstances connected with its construction, which ought not to have occurred during the execution; he should not, however, have the slightest hesitation in certifying to its efficiency, having regard to the well-known competency of the persons who executed the work.

Reverting to Mr. Braidwood's Paper, he thought it could not be too much urged, on persons having the care of works exposed to danger from fire, to look to the substances that suffered least from the action of fire. Iron suffered materially, and wood might be utterly destroyed; but brick and earth in its various forms used as a plastic composition, would do more to protect substances acted on by fire, than almost anything else. He had found, that whenever a good coat of sound plastering formed a ceiling to a room, fire was arrested more effectually than by any other means; timber protected by a thickness of an inch, or an inch and a half of ordinary hair mortar, would arrest the action of fire for a long time; and when it was so well known, that buildings suffered most from fire taking place in the lower part and burning upwards, it was important to use such means as would prevent those consequences. He had explained in a recent publication* the mode used in Paris, of forming partitions and ceilings, with a superior kind of pugging, which he should like to see practically tested in this country, because it was quite consistent with economy, and he had great confidence that it would be found useful, if properly carried into effect.

Mr. Braidwood, in answer to questions from the President, said, he had never found what were called fire-proof safes destroyed, and that those made by Chubb and Marr, of London, and Milner, of Liverpool, stood the best; whereas in a mere iron box, with single sides, the papers were generally consumed. Marr's and Chubb's safes had double casings of wrought-iron, with non-conducting substances, such as pumice-stone and Stourbridge clay between them. Milner's were also constructed with double casings, but with tubes of metal that would melt at a low temperature, and allow some liquid contained in them to escape and form steam round the box, with the intention of preventing the heat from injuring the contents. At the recent fire at Lincoln's Inn, one of Marr's safes was taken out of the ruins, and of the whole contents, only one paper was discoloured; all the rest were quite perfect. The papers in common safes, merely made strong enough to prevent

* *Vide* "A Guide to the proper regulation of Buildings in Towns." By Wm. Hosking, 8vo. London, 1848.

their being broken into, were generally found consumed. Wooden safes, covered with thin iron, were sometimes made; he had not seen any of them after a fire, but he expected the wood would be soon charred, as thin plate-iron on walls did not at all arrest the progress of fire. In wadding manufactories, the drying-rooms were frequently lined with iron plates, and when a fire arose there, the part covered with iron was generally found more damaged than the rest; the heat got through the sheet-iron and burnt the materials behind it, and there was no means of touching them with water, until the iron was torn down; sheet-iron should not, therefore, be used for protecting wood.

He had seen a case of an iron hearth, one inch thick, which had been laid down under a fire-grate, with a thickness below it of two, or three inches of slate and cement, yet the heat passed through the iron hearth, the slate and cement, and set fire to the timber beneath.

Professor HOSKING observed, that the use of thin metal, as a covering to wood liable to be exposed to heat, was a fatal error, as the metal rapidly conducted the heat and prevented the contact of water, in any attempt to extinguish the combustion. Nothing was more common in London, than to endeavour to meet the objection of exposing wood to fire, by covering it with metal, and nothing was more certain to be productive of mischievous consequences.

Mr. WHISHAW thought the division of large buildings by party-walls, similar to the division of large ships by bulk-heads, was the best preventive to the devastation of fires. There were many buildings at the water side, having lofts of great extent, whose convenience would not be injured if they were divided by party-walls; a fire would thus be confined to one of those portions, and the rest of the building would be preserved.

With regard to fire-proof safes, it was well known, that in large banking establishments the safes were moveable, and that during the night they were let down into dry wells, where there was no chance of their being touched, in case of fire.

Mr. COTTAM said, it was a common practice in London, for the surveyors of the insurance offices, to insist on a piece of sheet-lead being placed on a wooden floor where a stove was to be fixed; but he considered the lead quite as dangerous, or even more so than iron. When the Princess' Theatre was on fire, part of his premises also caught fire; on examination he found, that it arose from a piece of blazing wood being thrown over from the theatre, which, falling in the leaden gutter, had melted it, and the liquid metal passed through the ceiling on to a workman's bench where there was some oil, which it immediately set fire to.

On another occasion he had found, that the feet of a stove had melted the lead on which they rested; yet he had known it insisted upon, that a plate of cast-iron should be taken up, and a sheet of lead, 6 lbs. to the foot, substituted.

He had paid great attention to the state of iron after fires, and when the Argyle Rooms were burnt, he observed, that some of the cast-iron columns, 5 inches in diameter, and 12 feet long, though still standing in the morning, were curved nearly 4 inches in the centre, from the effect of heat on one side, and of cold water on the other.

Notwithstanding the occasional failure of iron, he was convinced that, if properly constructed, a fire-proof building, with iron columns and girders, brick arches between them, and tile and cement roofs, would succeed. He had rebuilt his workshops in that manner and although a carpenter's shop next door took fire, and large flakes of burning wood came down on the roofs, yet they sustained no injury, because the fire falling on a thickness of three tiles and cement, was easily extinguished.

He had observed wrought-iron to be crippled and doubled up with the heat, when cast-iron in the same building had resisted the action of the fire. He thought the hollow box girders of sheet-iron, which were strongly recommended in preference to cast-iron, would not stand: they were made of sheet-iron, three-sixteenths of an inch in thickness, and carried 13 tons 13 cwt., with a deflection of only an inch and seven-eighths, in a length of 31 feet. He thought, however, if they were heated,—and very little fire would heat such thin metal,—they would sink immediately: at all events, he should not like to guarantee any such tubular girders to endure heat, however well they might succeed, whilst cold; being hollow, there would be a draught of air through them, which as long as it was cold, would tend to preserve them, but if the flame entered, they would soon fail.

At the great fire in Marylebone, when forty houses were burnt down, there was not a piece of wrought-iron in the whole square, which was not crippled, though he found a great many cast-iron beams uninjured, and in their original positions. It was most essential, when columns were erected, that they should have a sound base to stand on: many of the failures of cast-iron columns, should rather have been attributed to the failure of their foundations, than to that of the metal, or the indequate proportions of the columns.

Mr. Farey said, he had paid much attention, practically, to the subject of fire-proof buildings. At an early period it was thought an object to avoid the cost of insurance, and the fire-proof buildings,

were substantially constructed: there had, however, since grown up a mode of constructing them at a cheaper rate, and it was found, that many of these cheap buildings would not stand. Mr. Braidwood's Paper related to that class of buildings, which were built to contain great quantities of inflammable materials, and his opinion of them was quite correct. There was nothing better for such structures than the old Roman system of strong pillars of masonry, supporting groined arches; but that was distinct from the question relating to mills and dwelling-houses, which Mr. Braidwood had not touched upon, and to which he thought the principles laid down were not quite applicable. The construction of fire-proof buildings, introduced by Mr. Strutt, of Belper, forty years ago, was exceedingly perfect, for buildings wherein there was no great accumulation of inflammable materials. If only the same strength of girders was used, when the arches were extended from 9-feet span to 12-feet span, it was not surprising that accidents occurred.

Mr. Farey was not aware of any dwelling-house, except that of Mr. Peter Fairbairn, at Leeds, which was built fire-proof, and still had all the comforts of an ordinary house, and none of the inconvenience which a fire-proof building was expected to possess.

Fire-proof buildings might be classed under three heads:—warehouses for containing inflammable materials; warehouses for non-combustible goods, and for manufactories and mills (this class required large unencumbered spaces): and public buildings and dwelling-houses. The principles relating to the latter class of construction were quite in their infancy, and he considered, that it would be a great contribution to their present knowledge, if any one would throw light on the subject. The great danger was in the staircases; and he thought, that if the owners of houses were compelled to pay an extra tax for constructing wooden staircases, or suffering them to exist in houses, now that stone and slate were so cheap, it would have a good effect. He also believed, that the system of insurance rendered people careless.

He agreed with Mr. Braidwood, in the danger of relying upon the support of cast-iron columns, and thought, that the construction of some shops, which he had lately noticed were entirely dependent on such support, most unsafe, even in case of a settlement of the foundation, and much more so in case of fire. The best lateral tie for arches was hoop-iron, properly applied, and he suggested its more constant employment in all arched buildings; also where tie-rods were used, they should be buried in the brickwork.

Professor Hosking remarked, that under the 14th Geo. III., regulating the construction of warehouses, none could be built

containing more than thirty-five squares, and now it was provided, that there should be a party-wall, restricting the contents to two hundred thousand cubic feet. It was required by the existing law, that if staircases were of stone, they should be supported by incombustible materials; but instances would be found in many houses, built since that law came into operation, where stone staircases had been made to depend entirely on timber partitions: these were cases in which Government interference would have been beneficial..

Mr. PIPER said, it appeared to be understood, that for the class of buildings intended to contain combustible goods, the construction should be of fire-proof materials, but entirely omitting metal. Notwithstanding the lesson given by the Great Fire in 1666, there was no record of any effort to improve the construction of dwelling-houses, by rendering them fire-proof, until upwards of one hundred years afterwards. In 1776, a model fire-proof house, by Mr. Hartley, was constructed, and was still standing, on Putney Common, upon which several experiments were tried, in the presence of their Majesties and the Lord Mayor, and a record of the trials was carved on the Obelisk, erected there by the Corporation of the City of London. It recorded, that the lower floor was nearly filled with combustible material, and whilst they were burning, the experimenter remained in the upper floors without injury. In that case the timbers, which were of the ordinary construction, were covered with thin plates of iron; but although the inventor had £2,000 voted to him by Parliament, he did not induce the builders to enter into his views, and the system was not extensively practised.

The next attempt was that by Lord Mahon, afterwards Earl Stanhope, who described, in a Paper read at the Royal Society,* his method, which was in substance, nearly identical with that mentioned by Professor Hosking. It was, in fact, the application of a kind of pugging, which was now generally practised, and was described to consist of laying between the joists an intermediate flooring of laths, to be covered with a plaster cement of ordinary lime and hair. It was, however, suggested, that chopped hay was better for the purpose than hair, because it was less liable to crack. The Paper then detailed very accurately the mode of placing fillets between the joists, laying the laths upon them, and covering them above and below with the composition, taking great pains, that it should be entirely closed; passing it over afterwards with a liquid composition producing an air-tight mass, and protecting the wood from the direct action of the flame.

* *Vide* Phil. Trans., 1778, page 884.

About the year 1826, a patent was taken out, which appeared not to have attracted much attention, for wrought-iron girders in the T-shape, upon which slabs of stone were to be laid. Since that time experiments had been tried in the neighbourhood of London, with a fire-proof cement, which was, Mr. Piper believed, only finely pulverized slate; this, it was found, would not adhere properly, besides being so exceedingly soluble, that the least application of water removed it at once; and as it did not set, or harden well, it was shaken down by the ordinary vibration of the building. As a proof of the identity of the process proposed by Lord Mahon, and that now practised at Paris, it should be stated, that his Lordship filled up the underside of a staircase with the materials, according to his system, and though it had only the ordinary wooden frame and steps, and was covered with combustible materials, when they were ignited the staircase itself was scarcely injured. This was a matter in which there had been Government interference, for by the 14th Geo. III., cap. 78, it was enacted, that warehouses should be confined to thirty-five squares, but there was no limit to the dimensions of dwelling-houses. In the new Act of Parliament the same kind of limit was prescribed, but in a different form, and it was directed, that there should be a party-wall at intervals of two hundred thousand cubic feet.

Mr. Piper had never seen a sound brick wall 9 inches in thickness burnt through; and, of course, if its thickness were increased to 18 inches, the security would be still greater.

With reference to the accidents and the forms which iron assumed, after exposure in a fire, the changes of pressure, and the extraordinary circumstances which then occurred, were such, that it was impossible to judge what might be the reason of the failures. He did not think it was just to entertain too great a prejudice against the use of iron. In buildings to hold combustible goods there should certainly be no metal; but for ordinary dwelling-houses, he did not think any better system could be devised, than to continue the use of wrought-iron beams.

Mr. Godwin must offer an opinion against the present mode of constructing buildings, for he thought, that not merely were the stairs constructed as if with a view to conduct fire from the bottom to the top, but that the hollow floors and partitions in dwelling-houses were really formed expressly for burning. These evils had frequently been pointed out, but as long as any increase of expense was entailed by a better system of construction, so long, he feared, would persons put up with the possibility of escape in case of fire, rather than incur a little additional expense for a properly-con-

structed house, and so insure the certainty of it. He would strongly urge all who had it in their power, to endeavour to perfect some cheaper system of building fire-proof houses, although he much feared, that without a greater degree of Government interference, it would never be arrived at.

One of the most admirable provisions in the present Act of Parliament, was that which insisted on accesses and staircases to public buildings being made fire-proof, and the late lamentable accident at Glasgow, showed how important it was, that every person within a theatre, or church, or any public assembly, should feel certain of there being an easy exit. The Covent Garden Opera, which was the only theatre built in London since the passing of that Act, had staircases constructed on that safe principle, and in the recent alterations of the Adelphi Theatre it had also been especially attended to, by placing stairs of Llangollen flag-stone, and by adding two other fire-proof staircases, as additional means of exit from the boxes and pit.

There were several new inventions for the application of iron for floors, which should, he thought, be discussed at the Institution; for instance, Messrs. Fox and Barrett's, Mr. Beardmore's, and Mr. Nasmyth's, but it would, he hoped, suffice to name them to induce a description of them to be sent.

Mr. DINES said, that Mr. T. Cubitt had made experiments on the strength of cast-iron girders of all forms, and also of brick and tile arches.* He admitted the danger of cast-iron, where it would be affected by any great heat; but he did not think, that in a fire in a dwelling-house, sufficient heat would be generated to be very injurious, as there was very little change in cast-iron up to a temperature of 600°. He had tried experiments, by igniting intense fires under brick arches of 4½ inches in thickness, and found that, in general, the tie-rod was the first part that failed. He was convinced, that the chief objection to the general introduction of fire-proof dwelling-houses, was the increase of expense of construction, which would, however, be to some extent compensated for, by the lower rate of insurance.

Mr. BRAIDWOOD observed, that after a fire at a sugar-house at Leith, which was built on the usual fire-proof principle, with iron columns and girders and brick arches, nothing remained but a heap of ruins. He did not mean to say, that generally speaking, there would be enough fire in any dwelling-house to destroy the iron, especially where it was well plastered; in his Paper, he had referred solely to large warehouses, in which large quantities of goods were

* *Vide* Minutes of Proceedings Inst. C.E., 1841, pp. 116 and 136.

stored. It appeared to him, that for dwelling-houses, iron was quite unnecessary, if the stairs were carried upon brick walls and well plastered beneath, or even if the French plan was adopted, of filling up beneath the steps with mortar, so as to allow no draught under them. The staircases at Lincoln's Inn were of wood, and the floors were made hollow, allowing the fire, which no doubt occurred from a flue, or fire-place, to spread and to obtain complete hold of the building, before the arrival of the fire-engines.

Mr. C. MANBY, Secretary, read the following communication, which he had received, relative to the subject under discussion.

DEAR SIR, St. Paul's Churchyard, March 6, 1849.

I REGRET that something unforeseen has occurred, which will prevent my attending your Meeting this evening, as I had fully anticipated doing, and stating, by permission of the Chairman, two or three points relative to the construction of strong rooms and fire-proof safes.

1st. As to Strong Rooms.—I consider, that for ordinary houses, a strong room constructed with a wall of 14 inches thick, and the door made of wrought-iron, is amply sufficient for protection from fire. For banks and large buildings the plan which I have seen adopted, is a system of double walling, with an open space between, the outer wall being 14 inches in thickness, the inner wall 9 inches in thickness, and the space between them 6 inches or 9 inches; when this plan is pursued, I submit that there should be a second wrought-iron door, and in all cases wrought-iron girders and ties should be used.

2nd. As to Fire-proof Safes.—The use of iron safes are, in my opinion, as much for the protection of property from violence and fraud, as from fire. Those made by us are constructed as follows:—The outer plates are of strong wrought-iron, dove-tailed together, and secured at all the corners and edges, by strong angle-iron; they are lined with hard sheet-steel, to prevent any drilling, or cutting tool, gaining access to the interior. The inner lining plates are placed at a distance from the outer plates, (varying according to the size of the safe), and forming, by the addition of very thin inner plates, one, two, or more separate compartments, which are filled with different non-conductors, those usually employed being pumice-stone for the outer, and Stourbridge clay for the inner compartments, but I do not confine myself to these materials, as I have used some sorts of cement with much advantage. A great deal depends on the safes being strongly made, and properly put together, so as not to be injured, either by falling themselves, or by heavy materials falling upon them.

There are fire-proof safes made in the United States, which, I understand, are very successful; in these the interstices are filled with gypsum.

3rd. The Position of Iron Safes is an important matter.—The too common practice of fixing them in walls, causes their exposure to heat, in cases of fire, much more than when they stand apart, so that they may fall with the floor on which they are placed. If a safe is made as it ought to be, it will not be damaged by the fall, and will escape the great heat, by being amongst the rubbish. Indeed, I have known many common iron safes thus placed to preserve papers, when others of a similar description, and in the same building, but fixed in a wall, have had their contents completely destroyed.

In conclusion, I may perhaps be allowed to state, that my late Father, and

myself, have made and sold some thousands of our fire-proof safes, and in no instance have we had a single complaint of their insecurity, either in case of fire, or in attempts at robbery.

I am, dear Sir,

To C. Manby, Esq.,
Sec. Inst. C. E.

Yours faithfully,
(Signed) JOHN CHUBB.

Mr. R. STEPHENSON, M.P., *V.P.*, said, he should like to submit one, or two remarks in the form of questions, as there seemed to have been some misapprehension of the intent of Mr. Fairbairn's original Paper, and of Mr. Braidwood's, as the sequence to it. The former Paper rather had in view, the establishment of certain principles for the construction of fire-proof buildings, and it described how these were to be executed, by the introduction of cast-iron beams and brick arches in floors, whilst Mr. Braidwood's Paper was rather an examination into the effect of fires upon metal beams in such fire-proof buildings, and thence drawing deductions somewhat unfavourable to that system of construction; there was a broad distinction between the objects of the Papers, and the mode of treating the subjects. He thought many of Mr. Braidwood's objections did constitute substantial reasons for not using metal beams in buildings liable to take fire; nevertheless, as the object of the former Paper was to introduce to the notice of the Institution a mode of construction for buildings, in a great degree removed from the danger of fire, it was scarcely open to the objections brought forward.

In the course of the discussion, it had been stated, that cast-iron under a temperature of 600° lost much of its cohesive strength; he had heard various opinions on that subject, and he should like to ascertain from Mr. Eaton Hodgkinson, whether the results of his experiments on the subject enabled him to agree with the statement in Mr. Braidwood's Paper, that when the temperature of cast-iron was raised, its strength was diminished, as much as was stated. It was desirable to ascertain correctly, the point at which any sensible diminution of strength occurred.

Mr. EATON HODGKINSON stated, that some years since, when investigations were pursued at the request of the British Association, to determine the relative values of hot and cold blast iron, some experiments were incidentally tried, for ascertaining the effect of temperature, on the bearing power of cast-iron. Mr. Fairbairn then had several bars tested at various temperatures, and the result was, that in the winter, and when they were covered with ice, some of the bars were bent, and broken under a very low temperature, and some at moderate and elevated degrees of heat: there was not, however, any great difference in the bearing power of cast-

iron, between the freezing point and when raised to 600°; but there was a sensible diminution of strength, when the temperature exceeded that point, or when the bar became perceptibly red-hot in the daylight.*

Mr. BRAIDWOOD gave, as the authority for the assertion he had made, the following passage from Mr. Fairbairn's Paper on the Strength and Properties of Cast-iron, published by the British Association:—"The infusion of heat into a metallic substance may render it more ductile, and, probably, less rigid in its nature; and I apprehend it will be found weaker and less secure under the effects of heavy strain. This is observable to a considerable extent, in the experiments ranging from 26° up to 190° of temperature.

"The cold-blast at 26° and 190° is in strength as 874 to 743, and the hot-blast at 21° and 190° is in strength as 811 to 731; being a diminution in strength as 100 to 85 for the cold-blast, and 100 to 90 for the hot-blast, or 15 per cent. loss of strength in the cold-blast, and 10 per cent. in the hot-blast." †

Mr. Braidwood had conceived that he could scarcely err, in assuming Mr. Fairbairn's own propositions, when discussing his Paper. He had not seen Mr. Hodgkinson's work when he wrote the Paper.

Mr. THOROLD said, it should be noticed, that the greatest danger apprehended by Mr. Braidwood, appeared to arise from the want of confidence on the part of the firemen, when engaged in extinguishing a fire, in a building of the construction alluded to. The effect of the water from the engines playing upon the beams must always be taken into account; the case mentioned by Mr. Cottam was an instance of this, where, from the application of heat on one side, and of water on the other, the columns were bent; it was well known, that a set of furnace bars would be destroyed, in a very short time, from a mere leak in the boiler, and the effect of steam only, on the underside of the bars, was to curve and twist them.

Captain MOORSOM said, it was difficult to estimate the intensity of the heat arrived at in fires in buildings. He then gave, as an instance, the case of an iron safe, containing important documents, which, during one of the fires in the forests of New Brunswick, had been conveyed as far as the bank of the river, with the intention of throwing it into the water, but the near approach of the fire pre-

* *Vide* "Experimental Researches on the Strength and other Properties of Cast-iron." By Eaton Hodginson, 1846, p. 378, art. 85.

† *Vide* "Seventh Report of the British Association, 1837;" vol. vi., p. 409.

vented its being done, and though the fire appeared merely to have passed over it, yet all the papers were charred and destroyed.

Major-General Sir C. W. Pasley had, some years ago, made some experiments at Woolwich, which demonstrated, that a very thin coating of brick-work would effectually prevent any injury to metal even under a temperature of nearly 1,200°.

Mr. BRAIDWOOD thought a main point to be considered, was the intense draught in large buildings, and he believed it was that which did the greatest mischief to the iron beams, and which, he contended, was proved by the condition of the specimens exhibited. He agreed in the advantage of the use of iron, in preventing a building from being set on fire from the outside; but, supposing a floor, say 90 feet long by 30 feet wide and 10 feet high, filled with cotton, once to become thoroughly ignited, and the draught permitted to be established in it, nothing but an incombustible substance could withstand it.

Instead of incurring expense in building warehouses with beams of cast-iron and brick arches, he thought, that they should be much smaller, and be well constructed, with beams and floors of wood only. He had seen a warehouse 450 feet long and 110 feet broad; now, if that building, although constructed on the fire-proof principle, was on fire, there would be no chance of dealing with it, though it would generally be considered safe. The draught of a fire in such a building would melt the iron away like lead. He had observed some warehouses within the last few years, that had been built in a very careless manner, and so as to encourage the spread of fire; there were large iron doors in the party walls, with space enough to insert a man's hand all round, between them and the walls. It was a rule, that wherever heated air, or smoke could pass, fire was sure to follow, and unless the iron doors were well inserted in the walls, fire was sure to pass from one compartment to another.

In his Paper he had not intended to extend it to the subject of fire-proof dwelling-houses; he thought, however, that if the staircase walls were always made of brick, or some solid material, and either stone, or slate stairs, or even wooden steps rendered incombustible by a ceiling of an inch and a quarter thick of good hair mortar, and well pugged, all the purposes of safety to human life would be attained. It was to be lamented, that that, or some equally simple plan was not adopted at present, as it would only add 5 per cent. to the cost of the building.

Mr. BIDDER thought, if Mr. Braidwood had been led into any error, it had been by taking the deductions from the experiments

of Mr. Fairbairn, instead of the experiments themselves. On examining them, he could not find any results which justified these deductions, and he thought they might well have arisen from a difference in the quality of the castings. The whole matter of fire-proof buildings resolved itself into a commercial question of insurance. A first-class building could be insured for about eighteen pence, or two shillings per cent., upon which the duty was three shillings per cent.,—certainly the lion's share; now, if Government interfered at all, the first thing it would do, would be to take care of the revenue. The question was, not so much whether life and property could be preserved, by a judicious alteration in the construction of buildings, as whether the expense of doing it would not be greater than the actual cost of insurance. It had been always supposed, that there were private interests at work, to prevent any precautions being adopted, unless forced by Government, who would not interfere unless the revenue was protected. The matter then resolved itself into this question, what would a company insure a building for? and whether that cost of insurance would not be infinitely less, than the interest of the capital which would be expended, in rendering such a building completely fire-proof, by adopting only brick pillars and groined arches, and having a complete system for extinguishing a fire, when it broke out among the goods deposited on each floor?

Mr. DINES stated, that in the experiments he had alluded to, the girder was heavily loaded, while the fire was made under it; when the lower part was hot, the girder had deflected, from the greater expansion of the bottom flanch, while the top was kept cool by water being thrown upon it; but as the fire went out, it recovered its original form.

Mr. HODGKINSON thought, that in drawing deductions from the experiments by him, and by Mr. Fairbairn, discrepancies might appear to exist, and yet both might be correct, as the results would be influenced by the extent of range included in the experiments. He still believed in the opinion given in his work on cast-iron, that "it would appear from the experiments, though the results were somewhat anomalous, that the strength of cast-iron was not reduced, when its temperature was raised to 600°, which was nearly that of melting lead; and it did not differ very widely, whatever the temperature might be, provided the bar was not heated so as to be red-hot."*

* *Vide* "Experimental Researches on the Strength and other Properties of Cast-iron." By Eaton Hodgkinson, 1846, page 378, art. 85.

Mr. BATEMAN mentioned the case of a large mill at Oldham, where the most effectual means had been taken, for protecting the building from fire, and a saving of £370 annually, (the amount of the insurance,) had been effected. There was at that mill a head of water of 250 feet, or 300 feet, and into every room of the mill, a separate pipe was introduced, governed by a distinct valve on the outside of the building; the pipes were all buried in the walls, and led into the ceiling, in which were a sufficient number of roses, or colanders, to deluge the whole space. An extra watchman was kept, and in case of fire, all he had to do was to turn on the cock commanding the room in which the fire took place, and the fire must be immediately extinguished. Mr. Bateman was not prepared to say whether a fire had ever been put out by those means, but he believed it could be done most effectually.

Mr. R. STEPHENSON, M.P., *V.P.*, said, the plan mentioned by Mr. Bateman, although no doubt good, as a measure of precaution, where the interruption of the working of a mill, in consequence of a fire, might operate very prejudicially upon the mercantile connections of a manufacturer, resolved itself entirely into a question of capital against interest. In the first place the expense of the waterpipes and apparatus must be added to that of the fire-proof building, which would have cost more, than if built in the usual manner; and then there would be the expense of the wages of the extra watchman. He thought these would amount to more than the usual charge for insurance.

Mr. BIDDER said, that quite as much injury was done by the water as by the fire, particularly in the cases of fire in dwelling-houses. The ultimate question was, what reduction the insurance companies would make, if the buildings were constructed on any certain fire-proof principle?

Mr. C. MAY thought, that in cotton factories, the high rate of insurance arose from the great value of the machinery, and the risk of injury to it in case of fire; it was possible, that, an extra expenditure of £4,000, or £5,000 in making a mill fire-proof, might save a very considerable sum for the insurance. His own impression was, that although it might be possible to render mills fire-proof, so as to pay commercially, he did not think there was any mode, by which the system could be extended to dwelling-houses with any pecuniary advantage.

As to the melting of cast-iron columns, he thought, that surrounding them with a thin coat of brick, moulded of the proper shape, would materially protect them, and tend to save property, as the metal columns would be protected both from fire and water. As

an iron founder, he knew that in lining a cupola for melting iron, a thickness of 3 inches or 4 inches of fire-clay would protect the external plates of iron, and enable an intense melting-heat to be maintained. If this thin coating was sufficient to allow iron to be melted within it, a coating of 3 inches, outside a column of cast-iron, would protect it effectually. It was a fact that when fires took place in warehouses where inflammable goods were stored, the iron columns appeared to melt very readily. At a large fire which took place at Fresh Wharf, near London Bridge, the columns all failed in that manner.

Mr. FIELD, President, gathered from Mr. Braidwood, as the result of his experience, that if the present extensive warehouses were subdivided into smaller compartments, fires would be less injurious, and would be more easily extinguished; a position which was borne out by the small premiums required for dwelling-houses, though they were more liable to take fire than warehouses. He had observed, that when an extensive floor was on fire, the draught occasioned such an intense heat, that the iron columns, girders, and roofs melted, and were destroyed with extraordinary rapidity; but when a fire was confined to a small space, it could be more easily dealt with, and additional security would be attained, by coating the iron with some fire-proof substance, such as brick, and having plaster ceilings.

He inquired whether Mr. Braidwood had any experience of putting out fires, by Phillips' mode of using carbonic acid gas and steam, generated by chemical means at the moment it was wanted.

Mr. BRAIDWOOD replied, that he had seen some of the experiments alluded to, and he thought water would have the same effect, except with regard to burning tar, or spirit, upon which water would not operate so quickly. When a fire occurred on one side of the street, and it was requisite to keep the other side cool, water was more effectual, because as the vapour was about the same weight as the atmospheric air, no force could drive it to the point where its action was required. The principal use of the system was for arresting a fire, and confining the damage to the room in which it broke out, or to the hold of a ship; but if fire had once fairly broken out, the principal reliance must be placed on the use of water.

Mr. RENDEL, *V.P.*, agreed, that the matter resolved itself into a commercial question, and that while it was cheaper to insure than to construct fire-proof buildings, persons would continue to run the risk of any loss from fire. It must be admitted, that small warehouses for containing inflammable goods were safer in every point

of view; but it must be remembered, that independent of the greater actual expense of the building, the land suitable for warehouses was of a costly description, and generally formed part of dock quays, or other similar valuable property, and it was considered better to incur the risk, than to waste the land in erecting a number of isolated buildings.

As the Institution of Civil Engineers was a society of practical men, he thought it the duty of every Member to bring those practical difficulties before their notice. The result of the discussion appeared to demonstrate, that it was safer and better to adopt the good old plan of having very strong wooden beams, and well-proportioned brick vaults. He feared, however, that as long as it was cheaper to insure, than to erect fire-proof buildings, the former practice would continue to be adopted by commercial men.

Mr. FAREY thought, a wooden building was but rarely erected at the present time for a cotton-mill, and that the case mentioned by Mr. Bateman, was contrary to the common practice. The reason why buildings of that kind paid such heavy insurance, was the great outlay for delicate machinery, which was always ruined in case of a fire occurring.

One reason which existed for constructing mills with great solidity was, that in the old wooden mills, the wear and tear of the machinery, consequent on the vibration, was twice as great as in the more modern buildings, with iron girders and columns, and brick arches. It was exceedingly difficult in a mill, with wooden beams, to keep the machinery in working order; therefore, assuming the manufacturer to seek only the most economical means, it appeared certain, that in mills containing valuable machinery, the actual system of constructing fire-proof buildings was considered essential.

Mr. BATEMAN explained, that the building he had alluded to had been built at least fifteen years, and was of the ordinary construction, with wooden beams and floors, but not fire-proof.

With reference to the commercial question, although the ordinary wooden building cost twenty shillings per square yard of floor, and a fire-proof building cost twenty-five shillings for the same quantity, he believed, with Mr. Farey, that the latter was the more economical mode of construction.

He also mentioned the case of a large warehouse at Manchester, the property of the Earl of Ellesmere, which had been burnt down, and in the rebuilding of which the fire-proof principle was not adopted, because the Insurance Company would not make any allowance in the premium, between a fire-proof building and one of the ordinary construction, with wood beams and floors.

Mr. BRAIDWOOD said, that, on examination, he had found the experiments, from which Mr. Fairbairn and Mr. Hodgkinson had drawn their conclusions, to be the same, only that Mr. Fairbairn gave as a result, that the cold-blast lost 10 per cent., and the hot 15 per cent., at 190°, whilst Mr. Hodgkinson, from the same experiments, gave as his conclusion, that cast-iron lost very little under 600°. This difference of opinion between men having the best means of judging, proved to him more forcibly than ever, how very uncertain cast-iron must be, and how little trust-worthy it was in high temperatures.

Mr. FAREY thought it very desirable, that there should be a new set of experiments. About twelve months back he had examined the subject, and found the experiments so contradictory, that he regarded the whole matter as at present perfectly unknown.

Major-General Sir C. W. PASLEY said, he could bear witness to the fact, that, at the fire at London Bridge, which had been alluded to, the cast-iron girders, from becoming red-hot, and having water cast on them were rendered unserviceable, and were obliged to be taken down and replaced; all the stone in the building was also split. He was therefore of opinion, that stone and cast-iron, unless protected by some incombustible substance, were not fit for fire-proof buildings. He had observed, that when the brick-work in buildings had not been covered with wood-work, the effects of fire did not penetrate further than 2 inches, or 3 inches into it; from this he concluded, that arched brick-floors were better than any other mode of construction, and that wrought-iron ought to be used in place of cast-iron, unless the latter was properly protected.

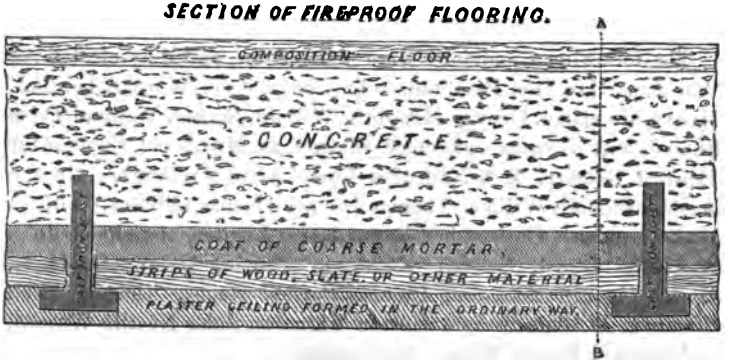
Mr. BARRETT begged to call the attention of the Meeting to a system of fire-proof flooring, that had been successfully adopted in the recent enlargement of Middlesex Hospital, and which had also been usefully applied for the roofs of buildings.

This system was the invention of Dr. Fox, of Bristol, who, about fifteen years since, erected a private asylum at Northwoods, near Bristol, which had, externally, the appearance of an ordinary brick building, but the floors were constructed in the following manner.

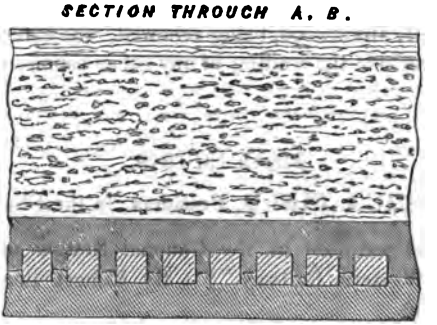
The joists were of cast-iron, of the ⊥ shape, placed 18 inches apart, and upon the flanges of these rested fillets of wood, about one inch square, and half an inch apart. A coat of coarse mortar was then laid upon these fillets, and portions of it passing through the spaces, formed a key for the ceiling: upon this coarse mortar there was placed a layer of pugging, or concrete, and finally a composition floor, composed of lime, ashes, and sand, well beaten down, and trowelled on the face. When the whole had become tolerably

dry, linseed-oil was rubbed over the face, so as to render the floor perfectly non-absorbent of moisture; the ceiling, consisting of a

SECTION OF FIREPROOF FLOORING.



SECTION THROUCH A. B.



coating of lime and hair, a floating coat, and a setting coat, was then applied beneath, in the usual manner.

Mr. Barrett considered that economy, as well as safety, would result from the adoption of this plan, for it appeared, from three different estimates which he had obtained, that the cost of this fire-proof flooring was only about two-thirds of an ordinary wooden floor, the prices being—

——	Cost of Fire-proof Flooring and Ceiling per Square.	Cost of Ordinary Timber Floor and Ceiling.
	£. s. d.	£. s. d.
For a room 14 feet square . . .	4 19 6	7 9 8
,, 18 feet by 16 feet . .	5 6 3	8 0 0
,, 35 feet by 18 feet . .	5 6 8	7 9 0

March 6, 1849.

JOSHUA FIELD, President, in the Chair.

The following Candidates were balloted for, and duly elected :— Augustus Hamilton Bampton, John Coode, John Wignall Leather, Henry Maudslay, George Meredith, William Scamp, William Price Struvé, and Thomas Colclough Watson, as Members; Captain Sir Edward Belcher, R.N., Charles Louis Aimé de Bergue, George Arthur Biddell, William Thomas Doyne, Thomas Gibbins, William Blake Lambert, Christopher Bagot Lane, Lieutenant-Colonel John Augustus Lloyd, Samuel Dickinson Martin, Henry Robinson, Henry George Robinson, Cusack Patrick Roney, Richard Allen Stickney, William Swann, Hutton Vignoles, John Neville Warren, and Edward Brown Wilson, as Associates.

The discussion upon the Paper, No. 767, "On Fire-proof Buildings," by Mr. J. Braidwood, being renewed, was extended to such a length as to preclude the reading of any other communication.

March 13, 1849.

JOSHUA FIELD, President, in the Chair.

No. 797.—"Description of the Camden Station of the London and North-Western Railway."* By Robert Benson Dockray, M. Inst. C.E.

The Camden Station is the southern termination for the goods traffic of the London and North-Western Railway. In the first design of the railway, the Act of Parliament for which was obtained in May, 1833, this station was intended as the sole terminus of the line. A very eligible site for a passenger station in the neighbourhood of Euston Square, giving immediate access to the New Road, having been suggested, an Act was obtained in July, 1835, enabling the Company to extend their line from Camden Town to Euston Grove. This extension was completed in time for the first partial opening of the railway, on the 20th of July, 1837, to Boxmoor. On the 10th of October in the same year, the railway was further opened to Tring; on the 9th of April, 1838, to Denbeigh Hall; and at the same time, from Birmingham to Rugby. The inter-

* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

mediate space, completing the whole distance from London to Birmingham, was opened on the 20th of September, 1838.

The extension to Euston Grove having been determined on shortly after the passing of the first Act of Parliament, no portion of the works at Camden Station were executed with a view to afford accommodation to the passenger traffic, and it has since simply remained the terminus for goods and cattle. The Engineer recommended the purchase of land to the extent of thirty acres, and after much discussion it was sanctioned by the Directors, many of whom thought the quantity preposterously large. So inadequate, however, has it proved to meet the demands of the traffic, that in addition to about fourteen acres, which have been covered with works at Euston, the Company have had to purchase three acres at Camden Town, to enlarge their works at that station.

The works on the old station were, 1st, the stationary engine-house, which consisted of vaulting, under the railway, adjoining the Regent's Canal; the boiler-houses opening to the railway, and two very handsome chimneys, which formed conspicuous objects in the district. Two condensing engines of 60 H.P., built by Messrs. Maudslay and Field, were used to draw the trains from Euston up the inclined plane, (averaging 1 in 85,) to Camden Station, whence they proceeded on their journey by locomotive power. 2nd. A locomotive engine-house capable of accommodating fifteen engines, together with the requisite fitting shops and offices. 3rd. Sixteen coke ovens. 4th. Two goods sheds and stabling. Together with a small accommodation for stores, and a shop for repairs of waggons.

The whole of these works, (except those of a temporary nature,) were constructed in the most substantial and permanent manner. In the design, every pains was taken to anticipate the wants of the traffic; yet such has been the rapid development of the railway system, that in the lapse of ten years from the opening of the line, it has been found necessary to sweep away almost every vestige of these works, and entirely to remodel the station.

It has been thought, that it would not be uninteresting to the Members of this Institution to trace some of the causes, which have rendered necessary so entire a change in the works, and so great a sacrifice of property. They are attributable, in the first place, to the large increase in the goods traffic, and to the change in the system of conducting that department; and secondly, to the increase of speed which the public have required in the passenger trains.

As to the goods traffic, it was the original intention of the Company to conduct this branch of the business, through the medium of

their own salaried agents. Such an arrangement was exceedingly distasteful to the public carriers, and their influence was so great that, in 1837, it was resolved to throw the line open to them. The shed which had been erected, although it would have answered the purpose of one carrier, was then found unsuitable for a number, for each firm required a separate warehouse under lock and key. Messrs. Pickford and Co. built a separate shed at their own cost, and shortly after, the Company built a third, consisting of one double and five single warehouses, which were let to the regular carriers, whilst those who only used the railway at intervals, were accommodated in the first shed. The traffic remained nearly stationary until the year 1845, when the considerable reduction made in the rates, was followed by a rapid increase of tonnage. Messrs. Pickford and Co. doubled the size of their shed; and the Company built a fourth, for the accommodation of Messrs. Chaplin and Horne. In July, 1846, the Act amalgamating the London and Birmingham, Grand Junction, and Manchester and Birmingham Railways was passed. Complaints became general, that the carriers stood between the public and the Company, and reaped all the benefit of the reduction of tolls: this point was so much urged in Parliament and elsewhere, that the Company, although unwilling to disturb existing arrangements, at length resolved to revert to their original plan of conducting the business through their own agents. This resolution has been recently carried out, and not a single private carrier now remains upon the line. The Company have purchased Messrs. Pickford and Co.'s shed, and have since erected an open shed for such articles as are not damaged by exposure to the weather.

As the increase in the traffic gradually progressed, great inconvenience was experienced by the want of sufficient sidings for marshalling the goods trains. The engines had to get up their steam an hour before they were required for the actual journey; and they were employed in drawing forward the train at intervals, until sufficient space was left at the tail, to attach more waggons. It often happened, that the train became so long, as to block up the arrival line for passengers, to the great risk of accidents. The point of junction of the goods siding with the main line, was removed from the Chalk Farm Bridge, to the entrance of Primrose Hill Tunnel, by taking down the bridge and increasing the width of the opening, and by widening the cutting to the tunnel; thus giving a length of double line for the goods traffic only, of 2,500 feet clear of the main line.

The space now occupied by the old engine-house will be filled up by extending the lines of railway in front. They are to be used

for sorting and marshalling the road station traffic, each siding being appropriated to a particular district, thus leaving the main goods lines clear for the long traffic.

As to the increase in speed, the competition amongst the various Railway Companies having demonstrated, that a high rate of speed was attainable, without any apparent risk of accident, the Board of Directors prepared to meet the wants of the times. Upon trial it was found, that the locomotive engines could surmount the inclined plane between Euston and Camden Stations with the ordinary trains, and that with the assistance of a second engine, the heavy trains could also be passed to Camden Station. A saving of ten minutes in time was the result, as well as economy in the cost of working the stationary engines and inclined-plane rope. After numerous successful trials, the engines and rope were, in April, 1844, abandoned, and in course of time the stationary engines were sold, and they are now doing duty in a flax-mill in Russia.

The saving in time thus effected was of little, or no value; and attention being directed to the locomotive stock, it was found, that even with two engines, the required speed could not be attained with the heavy trains. A number of locomotive engines of large dimensions were ordered, and by degrees the stock has been brought to consist almost entirely of this class.

It was found, that the engine-house was too short to admit engines of so greatly-increased a length, neither could they be turned upon any of the turnplates, without uncoupling the tender and blocking up the engines at one end with screw-jacks. It became absolutely necessary, that a new engine-house should be built, for it was useless to lengthen the existing house, because its dimensions were too small to receive the large engines. The position of the engine-house, intermediate between the passenger and goods lines had been admirably chosen, as the engines could join, or leave their respective trains, without interference with each other. As this space was now required for the goods traffic, it was decided to build two engine-houses, situated at opposite sides of the station, one for the passenger trains, the other for the goods trains; thus all fear of collision during the passing of the engines would be avoided. This alteration had become necessary, because the down passenger trains now passed at full speed through the station, which was no longer the locomotive terminus of the line.

The works executed since the general opening of the railway are the four goods sheds before mentioned, the passenger engine-house, the goods engine-house, the shop for repairing the waggons, the new Chalk Farm Lane Bridge, and the new bridge over the

Regent's Canal. Before describing these works, it may be remarked, that the Camden Station is on an embankment, averaging about 15 feet in height; the whole of the foundations have been carried up on concrete piers, sunk through the embankment into the substratum, and arches are turned from one pier to the next, upon which the superstructure rests, and hitherto, there has been no appearance of any settlement.

The passenger engine-house is a rectangular building 400 feet in length and 90 feet wide: it will hold forty engines and tenders of the largest class. It has ash pits throughout, and is supplied with water, so that the boilers can be washed out, in any situation where the engine may be placed. The roof, covering this building, is in one span of 90 feet; the rafters and purlins are of Memel, the braces and struts of cast iron, and the suspending and tie-rods of wrought iron. The latter consist of two bars 4 inches by 1 inch, having a sectional area of 8 inches, and the strain upon these bars is nearly 4 tons per square inch; each principal was tested in its place to insure the soundness of the welds. The roof is supplied with a continuous row of louvres, the standards of which carry the centre light. In cross section 48 feet out of the 90 feet are glazed with rough plate glass, weighing 4 lbs. to the foot.

The buildings at the back of this engine-house consist of a coking-shed, 250 feet long by 40 feet in width, having lines of railway which communicate by turnplates, with a double line of railway next the boundary wall, and is used for full and empty coke waggons. At the other end of the engine-house is a shed 150 feet in length, for storing coke: the space between these sheds is occupied by the offices of the locomotive department, stationary engine and boiler-house, fitters' shops, and store-room. The portions of the building, over the engine-house and store-room, are carried up to the height of 45 feet above the rails, each supporting a tank containing 5,000 gallons of water: they have also an intermediate floor which is used as a store-room.

The goods engine-house is circular, and 160 feet in diameter, having twenty-four lines of railway, each sufficient for an engine and tender, radiating from a central turnplate 41 feet in diameter. This form of building was found best adapted to the situation in which it is placed. The turnplate is one of Handcock's, made by Messrs. Lloyds, Foster, and Co.; the struts and beams are of oak. To guard against damage to this table, from engines running upon it from any line not corresponding with that on the revolving top, a strong casting is fixed round the periphery of the top, and projects upwards to the level of the rails. This casting has no apertures for the flanches of the wheels, except at the ends of the rails upon the

table itself: thus an engine cannot easily be run upon it, except when the revolving top is so turned, that the two sets of rails shall correspond.

This engine-house, which was built beyond the range of the general embankment of the station, is carried up on brick vaulting to the level of the rails. The roof corresponds with the plan: it is circular, without hips, or ridges: the interior height from the rails to the apex of the light is 67 feet. The ends of the principal rafters meet in a circular cast-iron curb, which carries the louvre standards, and the central light, of which the diameter is 30 feet. There is also a ring of light 10 feet broad, placed half way in the length of the rafters. This engine-house, like the others, is furnished with a coking-shed, offices, stores, and fitters' shop.

The construction shop is a building for the repair of goods waggons, and is so placed, that the entrance line crosses all the goods sidings communicating with them, by means of turnplates, which are also used for other purposes. It is 436 feet in length, and 70 feet in width, and is covered by a roof in two spans. It consists of a carpenters', smiths', and fitters' shop, together with the offices for supervision. This building is brought up to the level of the rails on vaults, which are appropriated to stables and general stores.

These three erections were executed in the most satisfactory manner, by Messrs. Branson and Gwyther of Birmingham.

It has been before stated, that it became necessary to remove the old bridge, in order to make room for the additional goods lines. The taking down the old arch, (as there was no room for centering,) required some care, in order not to interrupt the traffic. The parapet walls and spandrils having been removed to the level of the backing, and the arch stripped of the brickwork, except the two last rings, whole timbers were placed above the arch, at each face, and men standing on the timbers, with heavy crow bars, knocked off the edge of the arch, the timbers being drawn towards the centre, as the work proceeded, until the whole was destroyed: at stated intervals the débris were removed from the line below.

The new Chalk Farm Lane Bridge is one of Mr. Robert Stephenson's box girder bridges, the parapets, which are of boiler-plate, carrying the platform of the bridge. The top of the parapet, or box girder, is of cast iron, to which the sides of the boiler-plate are riveted, and it is finished by a cast-iron moulding. The platform consists of four cast-iron girders, 31 feet 6 inches in length, placed at intervals of 12 feet, the span of the bridge being 60 feet. The spaces between the girders are filled up with corrugated cast iron, the ends of these girders resting on the projecting flanch of the

parapet, or box girder; and in order that they may have a bearing on the whole width of the floor of the box, a casting was made of the same scantling as the cross girders, which was placed inside the box, opposite the end of each cross girder, and bolted to it through the boiler-plate.

It is believed, that this bridge is the first that has been erected upon Mr. Robert Stephenson's new plan; it was designed in July, 1846, and completed in January, 1847. The work was most creditably executed by Messrs. H. and M. D. Grissell, of London.

The bridge over the Regent's Canal forms a communication between the Camden Station and the goods shed built by Messrs. Pickford and Co. It is a wooden lattice bridge, the clear span being 66 feet 9 inches, and the depth of the lattice 9 feet: the lattices are halved together at their intersections, and secured by small bolts passing through each. When loaded with 100 tons equally distributed over it, the deflection on the centre was ⅞ths of an inch; on the removal of the load, the bridge immediately returned to its original level.

In addition to the works already enumerated, the station contains a cattle-landing, 600 feet in length, with pens for the security of animals until it is convenient to drive them to market.

A dock has been formed adjoining the canal, giving access, by water, for goods arriving at the railway, and similar accommodation is provided at the second shed. Messrs. Allsop are to have a series of vaulting, for storing their bitter beer.

A very complete engineering store-yard has been formed adjoining Chalk Farm Lane, and on the opposite side of the railway is the establishment of the contractor for the maintenance of the permanent way.

This terminates the description of the Camden Station, as it is proposed to be completed, and some idea may be given of the extent of the works by the following particulars:—

Length of single line of railway, exclusive of main lines, 12 miles 4 furlongs 10 yards;
Number of sets of points, 112;
Do. of turnplates, 196;
Do. of cranes, 110;

1	lifting	20	tons.
3	„	5	„
3	„	3	„
20	„	2	„
83	„	1½	„

Area of goods sheds, 135,380 superficial feet.
Do. of platforms, 30,566 ,,
Stabling for 427 horses.
Annual consumption of gas 6,404,000 cubic feet.

It was originally intended to supply both the Camden and Euston Stations from a well sunk under the old engine-house, which did not penetrate the chalk, but terminated in the green-sand. It being found, that this water was altogether unfit for locomotive purposes, an arrangement was then made with the Regent's Canal Company, by which the Railway Company was supplied with water from the canal, for which they undertook to return an equal quantity from their own well. This was effected by a double pump, working upon one axis; the one from the canal, the other from the well. As the traffic increased upon the railway, and also on account of the partial failure of the spring, the well would no longer supply the quantity of water required, and another arrangement was then made with the Canal Company, by which both pumps derived their supply from the canal, and the return of water from the well ceased.

In the new arrangement of the station, it became a question, whether it was not advisable to sink a well into the chalk. At Tring, and also at Watford, an abundance of excellent water had been supplied to the locomotive engines, ever since the opening of the railway; it was, therefore, presumed, that an ample supply of equally good water might be obtained, by sinking a well at Camden Station into that stratum. Mr. Robert Paten, of Watford, the eminent well-sinker, was employed to carry out the works. Down to the depth of 180 feet there is a shaft, 8 feet in diameter, of brickwork in cement, the upper 25 feet of which is lined with cast-iron tubbing, to keep out the surface water, and especially that which exudes under the embankment of the station, at the original surface of the ground, which is highly charged with vegetable matter; this portion of the well was terminated with a cast-iron plate, and the whole was found to be perfectly water tight. Through an aperture in the centre of this plate, Mr. Paten commenced boring down to the chalk, lining the whole with a cast-iron pipe, 12 inches in diameter, until he had pierced the chalk to the depth of 20 feet. The boring was then continued without lining, to the depth of 125 feet, making in the whole 400 feet below the surface of the rails, or 300 feet below Trinity high-water mark. Soon after piercing the chalk, the flow of water up the boring materially interfered with the workmen; a standard pipe was, therefore, erected in the well,

to the height of 60 feet above the cast-iron plate, and the operations were again carried on until it was presumed, that an adequate supply of water had been obtained. The standard pipe rising from the cast-iron plate to a level, above that to which the water would flow, was afterwards fitted with a slide valve at the bottom, by the shutting of which the well may, at any time, be pumped dry, the pump-clacks be examined and any repairs be executed. The water stands at a level of 44 feet below Trinity high-water mark.

This well is sunk under the passenger engine-house, and the same engine, (of 27 H. P.,) is employed to drive the machinery in the fitters' shop, and to pump water from the well. For this latter purpose there are two double-acting pumps, 8 inches in diameter, with rising main of 6½ inches; the first pump delivers the water into a cistern placed 90 feet below the top of the well, and the second lifts it into the tanks on the towers, provided for its reception. From repeated trials which have been made, the supply of water appears to be most abundant.

The water thus obtained was exceedingly soft, and perfectly clear, leaving no deposit whatever, after standing for many weeks in the tanks; but on its being tried in the locomotive engines, it was found to flush through the cylinders, and in some engines to such an extent, as materially to delay the progress of the trains. The water was then submitted, together with water from the wells at Tring and Watford, all in the same geological stratum, to Mr. Richard Phillips, who gave the following analyses per imperial gallon:—

WATER FROM THE WELL AT TRING.

	Grains.
Sulphate of lime	1·09
Carbonate of lime	14·72
Muriate of soda	1·38
Carbonaceous matter . . .	1·61
Solid matter . .	18·80

WATER FROM THE WELL AT WATFORD.

	Grains.
Sulphate of lime	0·94
Carbonate of lime	19·54
Muriate of soda	1·90
Carbonaceous matter . . .	1·32
Solid matter . .	23·70

WATER FROM THE WELL AT CAMDEN STATION.

	Grains.
Sulphate of soda . . .	13·00
Carbonate of soda	17·60
Muriate of soda	11·10
Carbonaceous matter . . .	2·30
Solid matter . .	44·00

The gases are in all cases the same, but the alkaline and earthy bases of the two first, which are excellent waters for locomotive purposes, are lime, and those of the last are soda. Why the presence of soda should produce the extraordinary flushing, appears involved in obscurity; but Mr. Phillips is carefully investigating the subject.

This well may, therefore, for the present, be considered as a failure, so far as the supply of the locomotive engines is concerned. The Railway Company, however, receive an excellent return for the amount expended, in the supply of the Euston hotels and their own tenants; but the engines continue to derive their water from the canal. The gross annual consumption is 22,880,000 gallons, of which the Euston Station takes 7,358,000 gallons.

The Paper is illustrated by a series of eleven drawings, (Nos. 4,405 to 4,415,) showing the different improvements which are being effected at the Station.

The Very Reverend Dr. BUCKLAND, Dean of Westminster, said, the part of the Paper coming most within his cognisance, was the quality of the water from the well. Every precaution had apparently been taken, to exclude the water from the sand-springs, and that derived from the plastic clay formation. The chalk had been perforated to an adequate depth, to procure good water; but there was an anomalous result, in finding water charged in a most unusual degree with sulphate and carbonate of soda, and from which there was an entire absence of sulphate and carbonate of lime, which salts were usually found in the water from the chalk. The presence of the salts of soda could only be accounted for, by connecting it with the fact mentioned by Mr. Clutterbuck, whose careful observations had been laid before the Institution, and who stated, that there existed a direct sympathy of action between the water in the wells, in the neighbourhood of Watford, and the rise and fall of the water in the wells of the great breweries in London. Within a few hours

after the pumping from these metropolitan wells ceased, the water level rose at Watford; and when an extraordinary amount of abstraction of water occurred in London, a corresponding depression was perceived at Watford. There was, therefore, evidence of direct and rapid communication between that district and the chalk, immediately beneath the metropolis. This rendered more perplexing the fact of the extraordinary discrepancy between the analyses of the water from the wells at Tring and Watford, and that at Camden Station. It appeared, that the soda was substituted for lime, and the question then was, whence came this large quantity of soda, and why was there no lime? The only explanation he would hazard was, that whenever it rained, the drainage from the surface of the London clay, and from that of the sand-beds and the plastic clay, caused a sudden flush of water into the dry gravel valleys, which, being cut across by deep holes, allowed all the dirty water charged with the manure of animals, the wreck of leaves, and other matters, to descend into the 'swallow holes' which abounded at the nearest point to London. Now, there might be a fissure, or fracture in the chalk, which established a direct connection between the particular district he alluded to, and the Camden Station well, so that water coming directly from the surface, charged with soda, would not have the same opportunity as the ordinary rain water, of absorbing carbonate of lime from the chalk, during its process of filtration, which generally required a period of several weeks. This hypothesis was the only apparent reason for the large proportion of soda exhibited by the analysis, presuming always, that the water from the sand-springs was effectually excluded from that derived from the chalk.

Professor GRAHAM corroborated the analysis of Mr. Phillips, as to the presence of carbonate of soda in water from wells in London, sunk into the chalk. He had found an equally large portion of carbonate of soda in the water from the deep well at Messrs. Combe and Co.'s brewery, and in that from the well behind the National Gallery, so that this quality was not confined to any particular well, but appeared wherever the chalk was overlaid by the London clay, producing permanent alkalinity. Soda was not found in the water from the chalk at Watford and Tring; but the chalk there was almost superficial, and not covered by clay: it was, consequently, a pure chalk water, containing little more than carbonate of lime, and losing its temporary alkalinity by boiling. Thus water from the chalk differed greatly, and it might be perfectly true, that in three cases, as stated, the process of filtration produced different effects, in different localities. The fact of the water at

Camden Station being unsuitable for boilers, he believed to arise entirely from its permanent alkalinity.

In the examination of water derived from different sources, he observed, that the addition of a very small quantity of alkali caused it to bubble up and burst into strong ebullition. The cure then, was evidently a simple one; it was to neutralise the alkali by waste muriatic, or sulphuric acid, of which a very small quantity would suffice, and which were both so cheap, that they might be used on the largest scale.

Dr. URE said, that about twelve years ago, he was employed to analyse the water from various sources for the London and Birmingham Railway Company; and when he discovered so large a quantity of carbonate of soda in it, he was no longer at a loss to trace to that cause, the priming, or flushing quality which was complained of, and he prescribed as a remedy, the addition of a small quantity of sulphuric acid to the water in a large tank. The action of priming appeared to take place more readily in a locomotive boiler, than in boilers of any other form. Now a locomotive boiler had copper tubes inserted within a casing of iron: thus there were two metals of opposite natures, and an alkaline solution, and he believed, that the voltaic action, thus induced, might have the effect of further increasing the priming, or at least, was in some way connected with the flushing in question. The analysis by Mr. Phillips was exactly the same as his own, exhibiting a large amount of soda, which had been, in some cases, a source of great annoyance to the brewers. A large brewery, lately, had an enormous quantity of beer spoiled, owing to the alkalinity of the water, which, dissolving more of the gluten of the malt than was desirable, prevented the yeast being worked off, and spoiled the beer. It would not be safe to employ sulphuric acid in any considerable quantity; but it was easy to get rid of the alkalinity by adding to the water a certain portion of sulphate of lime, and in that way obtain a hard water which was perfectly well suited for making ale. All the best Scotch and Burton ales were brewed with hard water, but soft water was preferred for porter breweries.

In answer to a question from the President, Dr. Ure stated, that as 200 gallons of the water in question contained about 1 lb. of solid matter, about one-third of which was carbonate of soda, about a fourth part of that third, or one-twelfth of sulphuric acid, would be a sufficient dose for the 200 gallons of water, great care being taken not to have any excess. He also thought the presence of the acid would not augment the galvanic action; but the experiment could be easily made.

Mr. CLARK inquired, whether the chalk water was thoroughly separated from the sand-spring water in the Camden Station well, because the water in the well he had sunk at Watford was decidedly from the chalk, and there it answered perfectly for locomotive purposes. He had made alterations to the wells at Harrow, Watford, and Tring, and the water was since supplied to the locomotives from those springs, without any inconvenience being felt from priming.

Mr. DOCKRAY said he believed, that the sand-springs were thoroughly excluded: every pains had been taken to 'tub out' the water from the upper strata; and the water pumped up was supposed to be entirely from the chalk.

Mr. HENRY MAUDSLAY stated, that the flushing referred to was not confined to locomotive boilers, for at Messrs. Maudslay and Field's engine factory, considerable annoyance was experienced by the priming from an upright boiler which was entirely made of wrought iron, the water used being derived from a bore from the sand on the premises. It would appear, therefore, that this effect must not be attributed entirely to galvanic action.

Dr. URE had understood, that in the boilers at the breweries, the highly alkaline water was used without the least inconvenience. He had no doubt, that the galvanic action aggravated the effect; but it was quite possible, that carbonate of soda might be the primary cause of the priming. The source whence the soda was derived, could be more appropriately investigated by the Dean of Westminster than by Dr. Ure; but he did think, that there must be some other cause than the hypothetical crevice. He was induced to state this, because no traces of potash were found by analysis, as would be the case if the water came rapidly from the surface. He believed none of the chemists, who had analysed artesian-well waters from the chalk, had found any traces of potash; whereas if there had been chinks in the surface, letting it down rapidly, they would have detected its presence.

Mr. JOHN DONKIN observed, that the water from a well, 250 feet deep, bored into the chalk, showed no tendency to flush from the boiler; there was merely a slight incrustation of carbonate of lime. In that instance, the water from the sand was entirely excluded, and the supply came from a depth of about 150 feet down in the chalk. He thought the presence of potash would not be injurious, as it would prevent any hard sediment, or incrustation taking place.

Mr. BIDDER, in reply to questions from the President, said, the only experiments he had witnessed, had been made with a view to prevent incrustation in locomotive boilers, in which the use of a

small quantity of muriatic acid had the desired effect. With regard to the presence of soda, he thought the results hitherto arrived at were not satisfactory. At Stratford, the water obtained from the greensand caused incrustation in the boiler, but it occasioned no inconvenient amount of priming. At Broxbourne, the water was taken from the New River: now if the soda was derived from the rapid passage downwards of the surface water, certainly it should have been found in those waters, because a considerable extent of surface drainage flowed into the New River, yet that water was found to be very good for boilers causing scarcely any incrustation. He was not at all aware of any experiments having been tried to prevent the priming, by introducing sulphuric acid into the tender.

The DEAN OF WESTMINSTER observed, that a tendency to rapid alkaline incrustation might be prevented, by putting into the boiler a few fragments of pure carbonate of lime. The incrustation of ordinary kitchen boilers might be prevented by the insertion of a few marble chippings, which would serve as nuclei upon which the deposition of soda would take place, rather than upon the metal.

Captain W. S. MOORSOM said, he was surprised to hear so much stress laid on the question of the analysis of the water, as he imagined that was a matter of minor importance, and in the present state of chemical knowledge, a remedy might be readily found. With reference to the other parts of the Paper, one of the most difficult points that had come under his notice, was the laying out a railway station, so as to meet satisfactorily the commercial purposes of the undertaking; it was exceedingly difficult to design it so as to be under adequate supervision, and so that the result should be economical in the delivery of goods and the arrangements for passengers. He would ask, with reference to the Camden Station, after the locomotives had delivered their charge, what was the amount per ton of goods, for porterage and horse-power, before that weight was lodged in the warehouse, or until it was delivered from the train to its ultimate destination.

Mr. DOCKRAY said, the cost of moving goods, after they arrived at the platform, varied so much, that no useful average could be ascertained.

Mr. WYNDHAM HARDING said, the cost of porterage in the stations, and storing the goods in the warehouses, must depend much upon the nature of the merchandise and the general arrangements of the premises. He thought, that the cost would be found to vary between ninepence and eighteenpence per ton, according to the general character of the line.

Mr. F. BRAITHWAITE said that, at first sight, it appeared strange there should be so great a difference in the analysis of the water at the Camden Station and at Watford, since they were both derived from the same geological formation: he thought, however, that it might be accounted for. Accurate measurements taken for the last ten years, at one of the principal breweries of the metropolis, showed indubitably an average yearly loss of nearly 4 feet of water in the London basin. It had also been stated, that the water at the Camden Station well rose within 44 feet of Trinity high-water mark. Many years ago, when there were but few deep pumps abstracting the water from the wells, the supply was derived entirely from the land water, or that which, falling on the upper edge, or crop of the chalk, percolated through the fissures to the deep, or London basin, thus forming the superior column; but the quantity of water pumped within the last few years had become so great, that the rain could not any longer supply the demand, and in several wells, instead of the water standing at a fixed level, it varied with the tide, clearly demonstrating, that as the balance of the upland water was lost, the influence of the sea water was more felt. It had frequently been suggested, that water impregnated with muriate of soda, would percolate through the fissures of the chalk, where they extended beneath the sea; now if this were the case it would account for the large quantity of salts of soda found in the water at Camden Station, although derived from the chalk as at Tring and Watford; the latter wells, however, being higher in the strata, and nearer the source of the percolating rain water, would not be subject to the same influence.

Mr. MCCONNELL said that, in accordance with the suggestions of Dr. Ure, the effect of a small quantity of sulphuric acid upon the water from the Camden Station well had been tried with some pilot-engines, and to a certain extent the result had been successful.

The boiler of No. 164 pilot-engine was washed out, and filled with well water; the tender was also washed out, and filled with 800 gallons of well water, with 3 ounces of sulphuric acid stirred into it. This engine ran to Berkhampstead, (28 miles,) before it began to prime.

The boiler of No. 75 pilot-engine was allowed to start without being cleaned; the tender was washed out, and had 1,000 gallons of well water and 3½ ounces of sulphuric acid put into it. That engine went out with the 4 P.M. train, and ran to Watford, (17¾ miles,) in twenty-two minutes, without priming at all; in fact, the driver could not perceive any difference between that and the canal water, which was generally used.

The boiler of No. 18 train-engine was washed out, and filled with well water; the tender was also washed out, and filled with 1,000 gallons of the same water, containing 3½ ounces of sulphuric acid. The train consisted of eighteen empty carriages, and the usual speed was attained in this case, as in the others, without any tendency to prime,—the only observation made in every instance being that the engines appeared to run "stiffer than usual."

In answer to a question from the President, Mr. McConnell stated, that the well water had been repeatedly tried for an engine alone, and it invariably caused such an amount of priming as to prevent its general use; the driver found it impracticable to work with it. The priming was not complained of during the experiments with the acid, except in one instance, where the engine began to prime at Berkhampstead, which, however, might have arisen from some other cause. It was very desirable to be able to work with the clean water from the well, rather than with the dirty water from the canal.

Mr. C. MAY suggested whether sufficient sulphuric acid had been used. Taking the proportions recommended by Dr. Ure, 6 ounces, instead of 3½ ounces, ought to have been mixed with 1,000 gallons of water. If, then, the experiments were successful, when imperfectly tried, great encouragement was offered for extending them, and employing the full quantity of acid. The specific gravity of the acid was not stated, as it should have been, in order to enable the calculation to be made for the proper quantity to neutralise the soda.

Captain W. S. MOORSOM said the question of a remedy for priming appeared to have been discovered very easily; for it appeared, from Mr. McConnell's statement, that formerly the engines could not work at all with the water from the well at Camden Station; but by means of the addition of a very small quantity of sulphuric acid in the tender, they had worked as well as with the water from the canal. He thought the question was one which ought, in the present state of chemical knowledge, to be considered nearly at rest. In all cases where he had worked a railway with water from the chalk, or the clay, or containing soda, or lime, or other matters, he had found, after a short time, by applying, in some cases filtration, in others a little chemical preparation, that the tendency towards priming was eventually done away with. When the railway was first opened, at Cheltenham, the incrustation in the boilers, after a comparatively short period of work, was full three-quarters of an inch thick; but it was soon got rid of by very simple means.

He was surprised, that Mr. Dockray had not yet been able to arrive at the average expense per ton of working the goods at

the Camden Station; as it was of great importance at a station where so large an amount of goods business was transacted. He had also been rather startled at Mr. Harding's estimate of ninepence to eighteenpence per ton as the usual expense; because as eighteenpence per ton was about the charge for conveying goods a distance of 18 miles along the line, if the mere movement in a station cost as much as the carriage for 18 miles, it was evident, that a considerable portion of the short traffic in goods could not be expected to come on railways. At five stations, on a railway in Cornwall, the average cost per ton of moving and distributing goods, chiefly mineral and general merchandise, after the locomotive was detached from the train, and up to the time of delivering them out of the warehouse, or from the side of the railway, was considerably lower than that given by Mr. Harding:—

Station No.	Tons.	Per Ton.
1.	For about 44,250 mineral and general goods, the cost was	$2\frac{4}{10}d.$
2.	„ 36,510 „ „ „	$1\frac{67}{100}d.$
3.	„ 5,919 general goods . . . „	$9\frac{1}{10}d.$
4.	„ 8,424 goods chiefly agricultural „	$4\frac{8}{10}d.$
5.	„ 8,500 „ „ „	$4\frac{49}{100}d.$

This included all horses, porters, clerks, occasional labour, rent of wharfs, and stations, gas and oil, and all charges, except that of the general manager.

Mr. Wyndham Harding thought, that wherever there was a great variety of goods requiring to be hauled a considerable distance, with a considerable amount of labour, the cost on the whole would be found to be as much as he had stated, particularly when it was remembered, that very often an engine was only required to shunt carriages to form the trains, and that alone cost £1,200 per annum. The mere transfer of minerals from a train, into the hold of a vessel, bore no comparison to the expense of a town station, for general merchandise.

The question of the greatest importance, in relation to this subject, and that in which the Institution was most concerned, was, he submitted, the common charge against Engineers, that their estimates of expense of first cost were worthless; and that the cost of railways had invariably exceeded the estimates. It must be admitted, that railways had enormously exceeded all estimates, but a little inquiry would show, that only a small portion of that excess was to be attributed to the Engineer. It was seldom that as much as 50 per cent. of the expense of a railway, a short time after it had been opened, came properly within the range of the works of the line; these

might, in fact, be taken at about 40 per cent. of the whole cost, the rest consisting of land, interest, parliamentary expenses, carrying stock, and stations. With regard to stations, nothing was more common, than to open a railway without sufficient accommodation for the traffic, the managers struggling on for a few years, and losing traffic, but at last being compelled to incur the expense of proper accommodation. On examining the accounts of any railway, a few years after it was opened, it would be found, that the expenses of necessary alterations were enormous; that which had been neglected at first being of necessity completed more perfectly at last. The cost of the North-Western Railway, six months after 279 miles of the line were opened, was estimated at £10,300,000; two years after that period the cost of the same 279 miles appeared to be £12,300,000, and after two more years the cost for the same distance appeared to have been increased to £14,300,000. The Great-Western Railway, 129 miles, with the various branches, cost £5,900,000; in the next two years, the same extent of railway appeared to have cost £6,900,000; and in two years afterwards the cost was estimated at £7,700,000. That proved, that the really expensive parts of a railway were not the engineering works of the line, but that they arose from the deficiency of adequate provision for the wants of the trade, which the railway was intended to accommodate. Thus the Engineer was not to blame, as he could not be expected to instruct the men of business, forming the Direction, how to foresee the wants of the traffic to be developed by the facilities afforded. The time had, perhaps, come when capital accounts might be closed, as, to a large extent, there was sufficient accommodation afforded for a considerable portion of the traffic on every line; it was desirable, therefore, that the Engineers should analyse the working expenses, and endeavour to form some general approximation to a law, which would enable them, in future, to be more correct in their anticipations. The stations would be found to bear some ratio to the number of trains and the traffic on the line; for goods they bore a ratio to the tonnage, and for passenger traffic they would be in a ratio with the number of trains; and the workshops would bear an approximation to the rolling stock. If Members of the Institution would direct their attention to that point, it would be found useful in estimating the cost of new railways, and would tend more than anything else to bring future estimates nearer to the truth.

Mr. MAUGHAM stated, that a few years ago, he made an analysis of some water in a deep well at the India-rubber works, Holloway, and found a considerable quantity of carbonate of soda, with some

sulphate of lime; he thought it important to state the fact, as it was connected with the water in the London basin.

The gaseous contents in an imperial gallon were 8·5 cubic inches, of which 2·4 cubic inches consisted of carbonic acid. The solid contents per gallon were 48·26 grains, which were thus composed:—

Carbonate of soda	30·30
Carbonate of lime	5·52
Chloride of magnesium . . .	7·60
Chloride of calcium	·60
Sulphate of lime	·90
Silica	2·23
Oxide of iron	a trace
Organic matter	1·11
	48·26

The solid contents were carefully treated for iodine and bromine, but neither were present. The specific gravity of the water was 1·00071.

He had also made an analysis of the water at Watford, which was published in a Report of a Committee of the House of Lords, before which he had been examined. Mr. Paten had told him, that at Watford, after boring for water to a certain depth, the augers suddenly dropped through a considerable space, giving the idea, that there was a subterraneous lake underneath; he had also heard the same remark from others who had been engaged in sinking deep wells.

Although it was supposed, that carbonate of soda and sulphate of lime could not exist in the same water, it was shown, that they were both present in certain cases of recent analysis, and up to the present time the reason appeared to have escaped the researches of chemists.

He had found, that in the boilers of stationary engines, a pint of oil, or a pound of any kind of grease in 800 gallons of water would generally prevent priming, when it was caused by carbonate of soda; the alkali and the grease evidently formed a soap; but why soap should prevent the priming was to him inexplicable.

Mr. R. Stephenson, M.P., *V.P.*, knew of no instance where the use of grease in a high-pressure boiler could be justified. He had heard the President mention, that when a steam-vessel came from sea and entered the Thames, she began to prime at the moment of passing from salt to fresh water, and the invariable practice was

to inject a certain quantity of grease into the boiler, by which the priming was immediately stopped; but on the other hand, he knew that putting grease into locomotive boilers inevitably caused priming. When the Warrington and Newton branch line was opened, there were no water-stations provided, and at first some dirty water was taken out of a brook near Warrington, but as that was found to be inconvenient, recourse was had to a pond at a spinning-mill, close to the railway, which contained all the dirt and grease thrown out of the condensing engine. With that water, the locomotives could scarcely move out of the station, an effect which he attributed entirely to the grease. Every engine-builder knew, that after an engine had been repaired, if the men engaged in the repairs had been using candles inside the boiler, priming always occurred at first. There must, however, be some very different action in high and low pressure steam, since the same thing that would make a locomotive engine-boiler prime, would evidently prevent it in a marine engine-boiler; it might be, that the locomotive being made as small as possible, brought into play every circumstance that could contribute to the priming. If a small quantity of free muriatic acid was added to the water in a boiler, it would prevent incrustation as well as the muriate of ammonia; that was proved on the Norfolk line, where it was used for six, or eight months. It might not, however, be quite so safe to employ the free acid, as the muriate of ammonia.

A fortnight ago, a hard mass, similar to rock, which was said to prevent incrustation, had been sent to his factory at Newcastle. A large lump was put into the boiler on Saturday night, after it was cleaned out, but on Monday morning, almost as soon as the engine began to pump the water out of the boiler, it got dry. The preparation, it afterwards appeared, ought to have been applied to the well, where it might, possibly, have answered the purpose intended.

Mr. BRUNEL said, that there was one point on which he differed with Mr. Stephenson: he was aware of the extraordinary effect which the slightest particle of oil, or grease would produce in locomotives, and in marine boilers, but he was under the impression, that the action of priming was much more mechanical than chemical, and he thought that might account for the extraordinary discrepancy between the different statements made as to boilers of various descriptions.

Some years since, on a railway using a large number of engines, there was great inconvenience experienced from priming. All the chemical schemes which had been mentioned were successively tried, and for a time they succeeded in remedying it: they had been,

however, gradually abandoned, and the original water was again used without any chemical introduction, yet no priming now occurred; the engines and boilers, it should be remarked, had, meanwhile, been improved and were of a different construction.

Mr. C. MAY thought the experiments at Camden Station were not sufficiently numerous to allow of specific deductions; he would, therefore, suggest to the North-Western Railway Company, that further experiments should be undertaken,—that they should be conducted, not by engine-drivers, but by accurate and competent observers,—that a large number of trains should be run,—that the carbonate of soda should be exactly neutralised,—and that the same quantity of carbonate of soda should be added to the Tring and Watford water: it would then be seen whether that addition would make the Watford water prime.

Mr. MAUGHAM said that in a boiler of 12 H. P., in which New River water was used, containing sulphate of lime, he put 12 lbs. of carbonate of soda, which effectually prevented any priming, and when the boiler was cleaned out after being at work for six months, there was but little incrustation, which was easily removed. Mr. Beale, of Greenwich, suggested the experiment, which had succeeded admirably; the boiler was never blown out during the six months.

Mr. WICKSTEED quoted an analysis by Mr. Aikin, published during the inquiry as to Metropolitan water in 1834, from which it appeared, that the water of the East London Water-works Reservoir, which was taken from the River Lea, did not contain any muriate of lime, or muriate of magnesia, and but very little sulphate of lime; that water was used in the boilers at Old Ford, and did not occasion priming. The incrustation was very small, depending on the quantity of water used; in a boiler working twelve hours per day, which was cleaned at intervals of six, or eight weeks, the incrustation was not thicker than one-eighth of an inch.

Mr. HAWKSLEY said, that in his experience, he had always found the presence of greasy matter contribute to priming. With regard to the character of the water at Camden Station, he attributed it to the exhaustion of the stratum by the over-pumping in London, and the consequent withdrawal of a large quantity of water from the deep chalk strata, the vacancy caused by which was, no doubt, supplied from the sea, or rather from the brackish part of the Thames, by continual filtration through the crevices in the chalk stratum. He had found similar effects in other places where the water was procured from strata extending beneath the sea.

Mr. HOMERSHAM suggested, whether the high temperature of the tubes, as well as the small space between them through which

the steam had to rise, might not induce priming in locomotive boilers more readily than in low-pressure boilers.

Mr. Scott Russell observed, it was a well-established fact, that the soap which it was stated to be so advantageous to produce chemically, in order to prevent priming, would, if put into the boiler, occasion it.

Mr. C. May believed, that the pyrites with which the London clay abounded, was the great source of the sulphates found by analysis in the water.

Mr. Paten said he had bored the well in question, for the North-Western Railway Company, and the water was entirely derived from the chalk. He differed from the statement, as to the water in the London wells having sunk, on an average, 4 feet per annum for the last ten years; that at the Camden Station had not diminished at all. He also denied the statement, as to the water rising in the wells at Watford, on the cessation of the pumping in London, and mentioned several instances of wells in that neighbourhood, which still remained at the same height, although, of late years, several hundred thousand gallons of water per day had been abstracted from their immediate vicinity.

Mr. Davison confirmed the statement, that the principal wells in London had been sinking, if not at the rate of 4 feet, certainly at the rate of 2 feet per annum. About twenty years ago, the whole of the wells in London stood at Trinity high-water mark, and they were now 40 feet, or 50 feet below it.

Mr. F. Braithwaite said, it was comparatively rare to sink wells into the chalk, but the same falling off was observed in the quantity of water thence derived as from the sand. At Messrs. Reid and Co.'s brewery, channel tunnels were driven into a large body of water; the pumping drained the sand, and the well fell in. It was then decided to carry down the well 20 feet in diameter into the chalk, and tunnels were driven following the fissures in the chalk and flint. The quantity of water obtained was 196 gallons per minute, but only 90 gallons per minute could now be procured, and they had to obtain the remainder of their supply from the New River Company. The water had, of late years, sensibly diminished in all the wells sunk in London.

March 20, 1849.

JOSHUA FIELD, President, in the Chair.

The discussion upon the Paper, No. 797, "Description of the Camden Station of the London and North-Western Railway," by Mr. R. B. Dockray, being renewed, was extended to such a length as to preclude the reading of any other communication.

March 27, 1849.

WILLIAM CUBITT, Vice-President, in the Chair.

No. 798.—"Description of the Groynes formed on the South Rocks, for constructing the New Docks, at Sunderland."* By William Brown, Assoc. Inst. C.E.

THE effect produced by the construction of a series of groynes, and by the deposit of excavated material upon the South Rocks, at Sunderland, within the line of high-water mark, appear to possess sufficient interest to warrant a description of that, as well as of the mode of construction of the groynes. Before, however, entering into the details, it must be observed, that owing to the rapidly-increasing trade of the port of Sunderland, and to its insufficiency of accommodation, as well as to the many inconveniences to which the shipping has been, and is still subjected, by the narrowness of the river and its crowded state, especially during the occurrence of freshes, various plans have been proposed by several eminent Engineers, for the construction of docks both upon the north and south sides of the river, with a view to afford the necessary relief to the port.

Hitherto only one dock, of about eight acres in extent, designed by Mr. Brunel, has been carried into execution; it is on the north side of the river, and is not much used, in consequence of the difficulty of ingress and egress, in heavy seas, especially if the wind is from the northward, and eastward, the points most favourable for vessels proceeding coastwise for the Thames, when they are once at sea.

The works in progress on the south side, consist of a dock of twenty-nine acres in extent, a half-tide, or inner basin, of two acres and a half, and a tidal harbour of the same area, opening into the

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* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

river: these have all been designed by, and are being executed according to the plans, and under the direction of Mr. J. Murray, (M. Inst. C.E.,) who further proposes forming, as an essential feature of the scheme, a tidal basin of about three acres and a half, and an outlet, to the southward into Hendon Bay, so that vessels may, at all times, be enabled to proceed to sea, either by the new egress, to the south, or by the river, to the north, as at present. The whole of these works, excepting the tidal harbour, adjoining the river, are within, or to the seaward of the line of the high-water mark, and these groynes have been erected for the purpose of retaining the deposited material, and of arresting the sand and shingle, which naturally travel to the southward, in order to form a barrier beach, which shall effectually exclude the sea, from beyond a given line.

Prior to describing the mode of their construction, it is necessary to direct attention to the timber groynes, (Plate 6,) and to the circumstances which led to their erection.

The sea has been gradually, but somewhat rapidly encroaching upon the Town Moor, and upon the ground occupied as a fort; the height of this table-land above the high-water mark varying from 32 feet to 36 feet. The banks are composed of a remarkably hard kind of marly clay, which stands nearly perpendicular, thus presenting the appearance of a cliff, resting upon the subjacent magnesian limestone, and at the bottom there is a slight accumulation of sand and gravel. On reference to the plan, it will be seen, that between the years 1737 and 1819, being a period of eighty-two years, an average depth of 50 feet was carried away; in the next thirteen years, between 1819 and 1832, the average waste was about 70 feet, and during the next thirteen years, between 1832 and 1845, about 23 feet; being, for the first period, upwards of 17 inches per annum, for the second, about 64½ inches, and for the last, upwards of 21 inches. At a point opposite the corner of the barrack wall, a depth of nearly 300 feet appears to have been taken away.

To prevent, if possible, so great a waste of ground, and as a protection to the steam-engine erected by the Durham and Sunderland Railway Company, a proposition was made to erect a retaining wall in front of the moor, somewhat similar to the one at Brighton. The directors applied to Mr. Murray, who at that time was Engineer to the Commissioners of the River Wear, as to the feasibility of such an erection; and he recommended the simple construction of timber groynes, both upon the score of expediency and economy, as they were intended to retain a portion of the sand which naturally travels to the southward; and thus to form a more

extended beach, upon which the sea might expend itself, and prevent it reaching the foot of the banks.

These groynes were composed of whole timbers having their lower ends let into the rock, and their upper ones secured to raking braces, the face being sheathed with planks 6 inches in thickness.

That they fully answered the purpose intended will be seen by reference to the high-water line, (Plate 6), which shows the creation of an area of about two acres of land, at the foot of the cliff. This accumulation of sand and gravel became so permanent, that the Railway Company caused a large deposit of ballast to be thrown over the cliff, parallel to the altered line of the high-water mark.

Of the groynes which have been constructed for the formation and protection of the barrier beach of the Sunderland Docks, the first, second, and third are of the form shown in Plate 6, the inner end of each being 10 feet above the line of high water of ordinary spring tides, and about 20 feet above the surface of the rock, whilst the seaward ends are only 2 feet 6 inches above the same surface: their lengths are respectively 326 feet, 326 feet, and 358 feet, and their crests form inclined planes of 1 in 18. By referring to the section, it will be seen, that the exterior is built with ashlar, and that the north side has a batter of $2\frac{1}{2}$ inches to 1 foot; the inclination of the south side being 1 to 1. The top, or crest, is formed into an arch, with a radius of 5 feet 6 inches. The interior, up to within 9 feet of the crest, where there is a bonding course 1 foot 3 inches thick, is filled with the excavated magnesian limestone, excepting, that the north side has a backing of coursed rubble, so as to make the wall 6 feet thick at the bottom, and 4 feet thick at the top; all the space above the bonding course, is also made up with coursed rubble, well packed, and built with mortar.

As a different form has been adopted for the other groynes, it will be better, before describing them, to show the reason of the alteration, by noticing the effect produced by and upon those now under consideration.

The set of the flood tide in the offing is S. $\frac{1}{2}$ E., and at spring tides it runs at the rate of three miles and a half per hour; along the shore it is S.S.E., and owing to a counter current, the first flood as well as the time of high water, is about two hours earlier, and at the distance of half a mile, it is about one hour earlier than in the offing. This flood tide is caught, in the first instance, by the north pier, which may be considered as a great first groyne, and a considerable portion of the sand brought up by the tide is there deposited; in fact, upwards of thirty-five acres of land have been recovered from the sea, by the erection of this pier. The slope at

which the sand settles, varies from 1 in 40 at the upper end of the beach, to 1 in 60 at the low-water mark. The quantity of sand retained here is not constant, for the large amount which is accumulated during the neap tides and calm weather, is much lowered by a heavy sea: as much as 5 feet in perpendicular height has been known to be carried away, in a single tide; some other place must, therefore, receive what is removed. A portion of it is caught by the south pier, and is thus carried up the river until it arrives at the Potato Garth on the one side of the river, or at the Wave and Sand Trap, or, as it is otherwise termed, the Beaching Basin, on the other side. In these two places a portion of it is deposited, the remainder continuing its course up the river until it is checked by the land water, which causes it to subside, and form sand banks, which, in their turn, are washed to sea by the descending freshes. The quantity, however, which passes up the river is comparatively small, owing to the south pier being shorter than, and consequently, being overlapped by, the north pier; the largest portion still travels onward, until it is arrested by the groynes, which form, together with the deposited excavation between each, a foreshore, or barrier beach, the inclination of which is about 1 in 25, whilst that at the bottom of the banks, to the southward, where there are no groynes, is only 1 in 11, and sometimes even less. There is no doubt, therefore, that if it had been thought necessary to make the groynes longer, the beach would have been still more extended, like that behind the north pier.

It was originally intended to construct these groynes with sloping sides of 1 to 1; but the section was altered, and it would have appeared probable, that the nearly perpendicular form, given to the north side, would be more likely to arrest and retain the sand and other material, than if the inclination had been greater, while the south side would form a strengthening buttress to the expected accumulation on the northern side. It is, however, evident, that such a form has a tendency to act as a conductor to the waves which strike it, and to carry them forward, so as, when the sea is heavy, to scoop out the sand that had been accumulated during the calm weather: this effect may, perhaps, in part, be attributed to an eddy which is formed by the angle at which the waves strike it, for it has been found, that the flood tide, after it has passed the south pier head, proceeds directly to groyne No. 1, and meeting with its resistance, forms an eddy, or counter-current, which returns, along the beach northward and the glacis of the south pier eastward, until it rejoins the main set of the tide, after having described a circuit of about 1,200 feet.

A circumstance, which, at first sight, will appear somewhat singular, must here be mentioned. Any substance which does not float, and is not of such great specific gravity as to remain stationary at the bottom, on being carried down the river, almost invariably finds a resting-place at the back of the south pier, though it is clear, that the tide must be ebbing at the time it is carried down, else it could not leave the river; but the set of the ebb is from south to north, so that if it were carried into the run of the tide, it must necessarily proceed with it to the northward, and on the return of the tide, be, as might be expected, cast behind the north pier.

To account for this apparent discrepancy, it must be supposed, that the water of the ebb tide, after passing the head of the south pier, strikes that of the north pier, which projects 230 feet further to seaward, and having done so, rebounds and forms an eddy at, or between it and the south pier, where the substance is detained until the first of the flood, which immediately carries it in the direction of groyne No. 1, and eventually leaves it on some part of the beach between that and the south pier.

Owing either to the form given to this groyne, or to the eddy spoken of, or perhaps partly to both, the surface of the sand on its north side is 2 feet lower than on its south side; whereas, at each of the others, the sand stands on the north side fully a foot higher than on the south side.

At the time of the equinoctial tides, during the spring of 1848, when the groynes were completely isolated, there occurred an unusually heavy sea, which made a breach in both No. 1 and No. 3 groynes, at the same time loosening some of the stones in No. 2. These effects, it is worthy of notice, were produced at nearly the same point in each, namely, the intersection of the inclination of the groyne, with the line of high water of ordinary spring tides, showing that they required a greater degree of strength at that point, than at any other, owing to the momentum of the waves being greatest at, or about the time of high water, or at the turn of the tide; which is shown to be the case by the following observations made upon the height and velocities of waves. It was found, that at 1h. 45m. before high water, the velocity of a wave at the south pier head was 9 feet per second, its height being 5 feet 9 inches, whereas at the time of high water the velocity was 13·3 per second, and the height 6 feet. At 1h. 45m. after high water, the velocity was only 7·8 feet, but the height of the wave was then 7·33 feet; now the greater height and reduced velocity were, of course, occasioned by the wave meeting the descending water.

The circumstances, which have been detailed, led to the consideration, whether some other form might not be more advantageously adopted, in the construction of the remaining groynes, so as to insure greater stability, and at the same time to accomplish the main objects, of retaining the deposited excavation, and of accumulating any other material, which might be brought by the sea from the northward. The result was the adoption of the form shown in Plate 6, the sides of which are semicycloids, each being generated by a circle of 12 feet 9 inches diameter, whose bases unite at and form the apex, or crest of the groyne, which, at its inner end, is calculated to be like the others, at 10 feet above high-water mark, the end to the seaward being 7 feet below. The lengths of the groynes, Nos. 4 and 5, were designed to be 442 feet and 510 feet respectively, having inclinations of 1 in 26 and 1 in 30.

After the rock had been excavated, to the depth of at least 2 feet, below its average surface, a course of freestone headers, 3 feet long, was laid as a foundation, on each side, the courses above being also of freestone, set header and stretcher alternately; the hearting was of large-sized rubble, closely packed, the vacancies between it and the ashlar work being filled with small stones, and Roman cement, so as to insure a solid bed. At the depth of 6 feet below the crest of the groyne, and resting upon this rubble, ashlar masonry was introduced, in level courses, between the external walls and carried up as near to the crest as possible, the remaining vacancy being filled with small rubble and Roman cement. These groynes are further strengthened, for a distance of 80 feet, above the intersecting points of high water, by having ashlar masonry introduced at the depth of 8 feet below the crest.

The construction of each groyne commenced at the seaward point, and as it became evident, that prior to their completion, a considerable portion of the upper ends would be buried, as was the case with those already constructed, it was deemed unnecessary, that they should be carried further than to the point of intersection of 5 feet above high-water mark; thereby reducing their lengths from 442 feet and 510 feet to 312 feet and 360 feet, which effected a considerable saving in the cost of construction, as the inner ends would have been the most expensive parts, owing to their continually increasing height.

Groyne No. 6 extends 578 feet 8 inches to the eastward of the line, where the heads would be 10 feet above high water, which line is distant 50 feet from the edge of the dock wall: the inclination given to the crest of this groyne is 1 in 32.

Groyne No. 7 extends to 557 feet 6 inches beyond the same line, the inclination being reduced to 1 in 30: in other respects, these are similar to those last described, excepting that No. 6 groyne is carried no higher, than to the point of intersection of 2 feet 6 inches above high-water mark, and the other only to that mark. The distance at which these several groynes are placed from each other, varies from 350 feet to 450 feet.

The quantity of material which, up to the present time, has been excavated and deposited between them, to assist in forming the barrier beach, is about 730,000 cubic yards: it consisted of the hard blue clay which forms the banks, and of the marly rock, or soft magnesian limestone, taken from the site of the dock, half-tide basin, lock pits, and entrance from the river into the tidal harbour.

The banks contain pebbles of quartz, different-sized pieces of granite and greenstone, together with boulders of clay slate, varying in weight from 3 tons to 7¼ tons, all of which must have been transported hither from the Cumberland mountains, though geologists are by no means agreed as to the circumstances which have attended, or the mode by which the transit has been effected.

It may, perhaps, not be uninteresting to observe, that one side of each of these stones forms a plane surface which is grooved in one direction, giving it the appearance of having been worn by passing over, or being passed over by other substances. Those who incline to the opinion, that they have been floated away on icebergs, may account for the circumstance, by supposing this to have been the only exposed portion of the stone, the remainder being enclosed by the iceberg.

Some of the largest of these boulders were found on the seashore, between the third and fifth groynes, rather to the seaward of their inner ends, indicating that the banks must have occupied those sites at no very distant period; for if those stones are supposed to have been moved at all by the power of the sea, as at present developed, it must have been inwards, inasmuch as that the backwater of a heavy wave, accompanied by the craving of the tide, though known to have a considerable effect upon sand and stones of small size, as well as upon floating substances, would not have sufficient force to move so great a weight as 7¼ tons, on a surface so nearly level as these rocks. At the commencement of Hendon Bay, where the rocks terminate, a very considerable number of these boulders, principally of the smaller size, are congregated, many of which have, doubtless, been washed there by the set of the tide.

It has been found, that the most regular and best consolidated beach is formed, by depositing the materials at and in a line with

the points of the groynes; but the Contractors are disposed, as a matter of convenience, to form high tips and allow the back sweep of the sea to form the beach, so that their tip ends may not be carried away. No portion of either the clay, or the limestone is visible between groyne No. 1 and the south pier, the entire surface being covered with a bed of clean sand, and there can be no doubt, that as soon as that part becomes surcharged, the space up to the next groyne will present a similar appearance, and so on to the entire extent to which they are continued.

Considerable difference of opinion existed as to the amount of leakage water which would be met with during the excavation of the docks, many persons being impressed with the idea, that fissures would be found to exist in the limestone, through which the water would rush at velocities, varying with the height of the tide, and in quantities so great as to render the carrying out of the scheme next to impracticable, especially when coupled with the Utopian dream of driving back the sea. The fears on that score are now groundless, for an engine of 35 H.P., working four pumps 18 inches in diameter, was found fully equal to carry off the leakage over an area of sixteen acres, as well as the surface water; and it was not until eight acres more were enclosed, that an additional engine was erected. All the foundations have been laid quite dry, and it is only in a trench which has been cut at 15½ feet under low-water mark, that the percolation of the sea water has been distinctly recognised. The barrier beach has withstood all the gales which, during the winters of 1847–8 and 1848–9, have been very heavy; in fact, instead of doing injury, they have invariably been of service, because they have improved its inclination, and so consolidated it, by washing the sand into, and among the clay and limestone, as to render it perfectly water-tight.

In executing the work, the great desideratum was to exclude the tidal water as soon as possible from a given portion: this was effected, in the first instance, (during the summer,) by throwing up a bank of clay between the dock and the half-tide basin, the deposit between the groynes being carried on as already described; but since this was not calculated to resist such gales as might occur during the winter season, a temporary coffer-dam was erected, so as to meet the inner end of groyne No. 3. Whilst the work was progressing in this division, another dam was placed to meet groyne No. 5, the deposit between the groynes being always in advance of the division whence it was taken. The last of these temporary erections is from groyne No. 7: the positions they severally occupied are represented on the plan by dotted lines.

The foundation-stone was laid in the half-tide basin on the 10th of February, 1848; since which time, now just a year ago, about 580,000 cubic yards of clay and rock have been excavated and removed to the barrier beach, and about 20,000 cubic yards of masonry built into the walls and entrances. During the months of August, September, and October, the average weekly excavation was 25,600 cubic yards, and of masonry built 1,100 cubic yards.

It is proposed to open a portion of the dock, at the beginning of next year; for which purpose a coffer-dam is to be placed at the southern end of its third division, which is to be considered as permanent, until the further works to the southward in Hendon Bay shall have been completed.

This Paper cannot be more appropriately concluded than by attaching to it the opinion expressed by Mr. Robert Stephenson, (V.P. Inst. C.E.,) on the day upon which the foundation stone was laid. He said "he had seen the commencement of the success of an Engineer's project, which, he must confess, in the first instance, he could not look upon without hesitation and some doubt. When he first received information from Mr. Hudson, the Chairman of the Company, that he would not enter into that enterprise, without Mr. Stephenson could satisfy his mind, that it would not only be beneficial to the town, but also be productive to the proprietors, and that many suggestions were to be subjected to him for examination, —he must say, that when he entered upon that investigation, his mind was subjected to considerable doubt; but after much consideration, and not without some anxiety and toil, he felt, that if he did not give his sanction to this undertaking, he would be jeopardising, not only the interests of the town, but also be injuring the prospects and talents of an individual. The arguments in favour of the undertaking were so clear and lucid, that he could not resist the conclusions which Mr. Murray produced. He arrived at this point, that, amidst the probabilities of success, the improbabilities were of no value."

Mr. Stephenson's conclusions are now those of the public generally. The works are rapidly progressing, so that, in a short time, Sunderland will possess a commodious dock contiguous to the seat of trade, and thus increase most materially its future prosperity.

The Paper is illustrated by a series of diagrams, from which Plate 6 is compiled.

Mr. J. Murray said, that the Paper required some explanation as to the set of the tide. The description was written before the

PLATE 6.

deposits had become so extensive as they then were, and the set of the tide upon the first groyne was very great; indeed, the run of the waves from the north was so heavy, that he was in doubt whether the first groyne should not have been placed a little nearer to the south pier. It was of importance, however, in connection with the entrance to the harbour, to obtain a bay for beaching vessels, because when entering the harbour, if they missed the mouth of the river, they either ran on to the north, or the south side; and in the latter case, without a flat shore, or beaching bay, they would be in danger of going to pieces on the contiguous rocks. The old south pier, having become dilapidated, was pulled down by the Harbour Commissioners, and in place of rebuilding it on its old site, the pier was thrown back in a semicircular direction, for the purpose of forming a basin in which the waves should be arrested. In doing this, the stones of the old pier had been used as a rubble deposit, on which the new pier was erected; and to obtain a bay on which vessels could beach outside of this new pier, the first groyne was placed as far to the south as possible. The space between the south pier and the first groyne was now filled up, by the drifted sand and the excavated material from the new works, so that the extraordinary eddies mentioned in the Paper, no longer existed; the material was carried by the sea, and deposited in the form of a regular beach to the south, and he had no doubt, that when the spaces between the groynes were filled up, all eddies would cease, and the natural run of the current would be normal with the coast.

Mr. Leslie had seen the groynes, which seemed to answer remarkably well. The employment of groynes, at right angles with the shore, must depend on the local set of the current, and whether the sea broke directly on the shore, or rolled along it. The plan pursued at Sunderland seemed to be remarkably well devised and executed, particularly in the direction of the groynes, for instead of their being level, they dipped down into the beach, and thus the scour, which would probably have occurred across the extremities, was completely prevented. It seemed to him, also, that there was considerable merit in the mode of construction; for the courses of masonry, instead of following the inclination of the top of the groynes, were level, so that each course tailed under another, and thus made better bond for the top, than would otherwise have resulted.

Mr. Murray observed, that the spiral form adopted in the bonding courses of the groynes appeared to resist the action of the sea more effectually than any other kind of masonry.

In answer to questions from Mr. Cubitt, *V.P.*, Mr. Murray

stated, that a large quantity of sand mixed with gravel and other substances, travelled southwards, caused by the degradation of the coast and by large quantities of London ballast thrown overboard at sea by the colliers: it was important to arrest it during its progress, and, therefore, he had employed these groynes. When the prevailing wind was from the north, the sand and gravel lodged against the northern side of the groyne, whilst with the form used for the first three groynes, the deposit was swept out from its southern side; but when the wind went round to the southward, the deposit took place in an opposite manner. He was led to fix the positions of the first three groynes, from a desire to establish confidence in the general plan, by warping up a large space of land between them, as quickly as possible; and aided by the sand which came from the north, to form an opposing barrier against the sea, as a buttress to the works. The plan was approved of by the Admiralty, and during its execution in the winter the works were subjected to very heavy seas. The effect of the first two groynes was to arrest the sand travelling southward, and a bank was deposited between them, beginning, at first, to tail itself in the direction of the south pier until it met the first groyne, when the space was soon warped up. On removing the temporary barrier which connected the inner end of the groyne with the Town Moor Cliff, the sea swept away the top sand, and left nearly a clean beach to commence the excavations for the docks. This proved, that the sands could be accumulated, or removed, at pleasure. The material excavated was a soft marly limestone which, when first deposited, slightly discoloured the water, but it afterwards got intermixed with sand and gravel, which made the barrier, or embankment, on its seaward side nearly water-tight.

In answer to questions from Mr. Scott Russell, Mr. Murray stated, that the shore between high and low-water mark was nearly flat, and composed of magnesian limestone, into which, although timber groynes such as were first placed at the foot of the cliff might have been firmly fixed, yet subjected, as they would have been, to very heavy seas in a perfectly isolated position, he would have feared their powers of resistance if constructed of timber. Besides, if the first groynes had failed, the project might have been considered impracticable; he, therefore, considered, that the best plan would be to construct them of rubble-work; but on consideration, that also was discarded for ashlar masonry with a strong hearting of rubble. The masonry was built with blue-lias mortar mixed with pozzolano, and the joints pointed with the best Roman cement, because they had to stand the action of the tremendous seas that

rolled upon that coast, and in the latter groynes, the semi-cycloidal form was adopted, for the purpose of better bonding the masonry, by the spiral line formed by the joints of the diminishing arch: this had the desired effect in affording the greatest strength. As had been noticed in the Paper, the first three groynes had been breached by the waves, before the material had warped between them; but since the semi-cycloidal form had been adopted with ashlar bonding courses and rubble hearting, no injury had been done to any of them.

Mr. WALKER said, it was evident, that the construction of the groynes with ashlar rendered them stronger, and the form adopted gave the sea less hold on them. At the Plymouth breakwater, where the greatest experiment had been tried with rubble-work, the heavy seas continually displaced masses of the material and demonstrated very clearly, that rubble *per se*, even of large dimensions, could not resist the waves; now, however, since the whole surface had been cased over with ashlar, strongly dove-tailed, and bonded both vertically and horizontally throughout, it certainly stood, but even these precautions were hardly found to be sufficient.

It had been Mr. Walker's unpleasant task, to report unfavourably on Mr. Murray's original plan for damming the river Wear, but it was afterwards his more agreeable duty to approve most highly of his present plan for the new docks of Sunderland. Referring to the subject generally, he would ask, what effect was anticipated, when the space between the groynes was filled up, and the excavation of the rock beyond their inner ends was completed? and he also wished to know Mr. Murray's opinion as to the tendency of the sea hereafter acting on the sand, and leaving the groynes exposed at their outer ends.

Mr. MURRAY replied, that an eddy was formed between the south pier and the first groyne, but since the space had been filled up, the force of the sea was thrown on the second groyne and the eddy ceased; proving that if the high-water mark could be driven a little further out, as he intended, the barrier beach would remain nearly stationary. During the execution of the works, a nearly permanent beach had been formed, by the deposit of the excavated material: the space between the first and second groynes remained still to be filled up, and he had no doubt when that was accomplished, it would become a permanent beach. The groynes were placed at such angles in plan, and their crests dipped at such an inclination as, in his opinion, was the best for accumulating the travelling beach, and retaining the deposited materials from the excavations of the dock. If a retaining wall, like that at Brighton, had been con-

structed, it must have been built of such strength as to have resisted the action of the sea during its progress, and it would not have had the same effect as the groynes, in forming land by warping up a permanent embankment on the sea side of the dock which could, eventually, be rendered useful to the Company.

Captain W. S. Moorsom inquired the cost of the groynes, and what were the circumstances which determined the angles in plan, as they appeared to be almost all different; also the depth of the groynes, their distances from each other, and what line of overlapping was determined upon, as the best in practice. He presumed, that one main use of the beaching basin was to run a vessel into it with comparative safety, in case of its entering the harbour in distress.

Mr. Murray replied, that the cost of the first three groynes, built chiefly of rubble, was about four guineas per lineal foot; the others, being of more expensive materials, cost on an average, seven guineas per foot. The inclination of the crest of the first three groynes was nearly alike, and was founded on long observation of the slopes of the adjacent seashore: the slope of the next two was increased for the purpose of obtaining a more extensive beach, because any land formed on the side of the dock would, as he had just stated, be very valuable to the Company. The inclination of the last two groynes had been increased still more, with the intention of forming a convex outline for the barrier when extended further south, which was contemplated for the purpose of warping up a beach, and when this was accomplished, the Dock Company had powers, by the Act of Parliament, of depositing ballast upon it. The original timber groynes were erected nearly at right angles to the Town Moor Cliff, and by means of them a depth of sand of nearly twelve feet had been warped up in six months. The accumulation of sand by the action of the wind was as remarkable there as on the coast of Holland.

Mr. Scott Russell begged Mr. Murray to describe the principle by which he had been guided in the formation of the wave-trap, and also to state whether after the waves came into it, their progress was easily arrested, as it was generally found easier to get the waves into a trap, than to keep them there innocuous.

Mr. Murray explained, that the sea in Sunderland harbour formerly ran with great violence along the north pier, and broke upon the Potato Garth, so that vessels under press of sail could not recover themselves, but were frequently driven on it and wrecked. To obviate this, a solid wall was built partially across it, parallel with the low water-line of the river; but it had the effect of causing

the waves to roll up the harbour, with such violence, that no ship could safely remain in the lower part of it. When Engineer to the Harbour Commissioners, he recommended a portion of the solid part of this pier to be opened by substituting timber framing, by which means the swell was very much reduced, in consequence of the waves being permitted to be thrown on the Potato Garth. He had formerly seen a huge wave rolling along a portion of the north pier, and making a clean sweep over that portion of it.

On the other hand, the north-east seas, struck the south pier with great violence and rolled along the whole line of it up the harbour, causing the vessels to lie very uneasy, in spite of the projecting jetties, which frequently threw up the spray to a great height. It being an object of importance to render the harbour as quiet as possible, it was his intention to form a small receiving bay, or 'claire-voie,' as in some of the French harbours, into which the waves would run and expend their force, and he had received instructions to proceed with such a work; but before commencing with it, the inner part of the south pier was injured by a heavy storm, which shook it very severely for a considerable length, and he then recommended it to be taken down, and the materials to be used in the construction of a wall, in a semicircular direction, to form a wave-trap of greater extent. The result of the formation of this receptacle was, that in stormy weather, the heavy waves from the north, and north-east, which struck the south pier, hugged its face and rolled along it till they tumbled into the trap, the higher portion of which took the form of a sloping bank of sand, on which those waves were dispersed. A portion of the old pier-head was left as a jetty to prevent the waves passing upward. The wave-trap had, however, become surcharged with sand, although it had been twice partially cleaned out; and unless it was kept in perfect order by periodically removing the sand and gravel, which accumulated during the winter season, the whole receptacle would, in time, be warped up and do away with its utility as a stilling basin. It would be for the interest of the Dock Company to co-operate in any measures tending to keep the receptacle in good order, as otherwise it would injure the entrances to the Dock, by lodging sand in the tidal harbour, and half-tide basin.

Mr. Scott Russell thought the facts Mr. Murray had given were of the highest importance: they had been often observed by Engineers, but until within a few years, had not been well understood. It had been stated, that when the sea struck either of the piers at certain angles, although a portion of the wave was undoubtedly reflected, the greater part hugged the face of the pier and run along it; now

that was in opposition to the acknowledged principles of the action of waves, and he believed the fact was not received until some experiments made by him showed, that at an angle of less than 30°, large ground waves, or swell, ceased to be chiefly reflected, and the greater part hugged the pier. That was an important fact, which ought to be generally known, and the want of knowledge of it had frequently led to serious mistakes in planning works: it was also important, as rendering practicable the construction of wave-traps, which had not yet obtained the attention their importance deserved. They demonstrated the possibility of guiding a wave in almost any direction, by placing piers at certain angles, so that the wave could hug the wall, and being led along into the wave-trap, could be there allowed to expand and roll quietly over the beach, breaking as it went, until its force was entirely expended. The results in this, comparatively, contracted wave-trap, appeared to indicate, that if it had been more extensive, its beneficial effects upon the quietude of the harbour would have been greater.

Mr. MURRAY replied, that if he had now to form the wave-receptacle, he should probably be induced to make it of a greater extent, but under the circumstances, he was unable to do so.

In the month of April 1846, at the top of a spring tide, thirty minutes before high water, with the wind blowing strong from the north-east, and a heavy sea running, Mr. Murray took some observations upon the velocity and height of waves rolling along the various parts of the piers, &c. A wave striking the north pier, and running inwards a distance of 550 feet, acquired a velocity of 11·71 miles per hour; its height being 7 feet from the hollow to the crest. A wave travelling at the east end of the wave-trap basin, from the stairs inwards, a distance of 500 feet, attained a velocity of 5·87 miles per hour; its height being 3 feet 7 inches. The height of a wave opposite the yards of the Commissioners, was 9 inches, but its velocity was not ascertained.

Mr. SCOTT RUSSELL suggested, that it would be of the greatest practical use, if Mr. Murray would cause regular observations to be made, of the height of a wave at the moment of breaking, and the depth of water in which it broke; secondly, when a wave was breaking, how far the succeeding wave was from it, or the distance from the crest of one wave to that of the following.

Mr. CUBITT, *V.P.*, thought the Institution was much indebted to Mr. Murray for the interesting information he had afforded. There did not appear to be any established rules, for either the direction of groynes, or their construction; all appeared to be done by the 'rule of thumb,' unless an Engineer was consulted, when he

generally applied the rules he had laid down for his practice in other positions. It would be very interesting if, in the course of this discussion, examples of series of groynes could be quoted, from which something like general rules could be deduced for ordinary practice.

Mr. RENNIE said, he believed the works designed by Mr. Murray were very judicious, and had materially diminished the inconvenience formerly experienced both in entering and in leaving Sunderland harbour; it had always been stated that the Potato Garth and the wave-trap were of great use, in permitting the expansion of the waves, and in tranquillizing them, after they had entered the harbour.

In a Report made in 1832, conjointly with Mr. Walker, he had strongly advocated the erection of new docks, opposite the Town Moor, at Sunderland.

It was admitted that groynes were, under certain circumstances, the best defences for a coast, for wherever the waves brought the sand and shingle in quantities, the seaward side filled up, while on the lee side it was generally scooped out; but by a judicious distribution of these groynes, such an accumulation of material might be produced, as would effectually protect a shore, or any sea works.

At Brighton it was found, that the cutting away of the groynes threatened the destruction of the sea wall: Mr. Walker and Mr. Rennie, therefore, recommended, that the groynes should be heightened, and since then, the evil had been remedied, and the sea wall was efficiently protected.

Mr. J. T. HARRISON said, the little experience he had on the subject of groynes was derived from observation of those on the South Devon coast, and he found there was some danger of their producing ill, as well as good, effects, because it not unfrequently happened, that whilst shingle and sand were collected on one side, any accumulation was prevented from taking place on the opposite side: the situation and the direction of the groynes were, therefore, very important.

Captain W. S. MOORSOM observed, that a good deal of skill had been exhibited, in placing the groynes on the South Devon coast, so as to accord with the action of particular currents, and there existed on that coast such local peculiarities, that he thought a most interesting Paper might be presented by Mr. Harrison on the subject. The force of the waves and the direction of the currents on that coast, appeared to be totally different from those illustrated by Mr. Murray. There must be an angle, at which the groynes ought, in all cases, to be placed, so as to resist the force of the waves, or the

current, and yet to retain the shingle: the difficulty was to arrive at that angle, and it could only be done by a careful comparison of numerous cases. Captain Moorsom then directed attention to a diagram, illustrating the construction of the timber groynes on the coast near Brighton, and stated, that an angle of 70° appeared, in that locality, to collect the greatest amount of shingle. These groynes, although of a more temporary construction than those at Sunderland, had been very useful for collecting and retaining the shingle, and their cost was only twenty-six shillings per foot-run, when made of beech-wood.

Mr. Scott Russell said, that where there was a very predominant current in one direction, it was necessary to provide against the excavating power of the waves, as well as to encourage deposition; and where there was a strong set of tide, or a current in one direction, if the groynes extended into deep water, the only method of meeting the difficulty was to place them at correct angles with the set of the tide, or current, so that accumulation should be encouraged, at the same time that the excavation on the lee side was diminished. Mr. Murray found, that at Sunderland, during part of the year, the predominant set of the current and the waves was on one side, and during the remainder of the year, it was on the other side; so that he had been obliged to come to a sort of compromise and to take a middle course.

The wave-trap had been mentioned, as if its advantages chiefly arose from its magnitude. There was no doubt, that the sooner a wave could be enabled to expand, after entering the trap, the sooner its force would be expended; but it was not judicious to place barriers, or projecting piers, in the way of waves, having their initial force, as it not unfrequently happened, that a wave being reflected, by a projection of masonry injudiciously placed, had done much more harm from its reflection than it would, if it had been allowed to travel onward, and expend its force gradually. After getting a wave into a trap, it was necessary to destroy it there, and that seemed to be effectually done by Mr. Murray. He had seen, on the outside of many harbours, much mischief arise from reflected waves; boats had been swamped and lives lost, close to vertical piers, from that cause. The great point to be attended to, was the method of absorbing the force of the wave, and there was nothing so good for that purpose, as providing on one side of the harbour a long sloping beach, towards which, if possible, the wave should be directed and there allowed to expend itself. He had seen many vain attempts made, to stop waves by spurs and other means, and by masonry in various forms. The plan of producing smooth water by an extended

sloping beach, at a less angle than 45°, was generally the most successful: if, however, the angle was greater than 45°, the waves were reflected and did harm.

Mr. BIDDER said, the wave-trap was effective, so long as the shingle had not accumulated to such an extent, as to entirely fill up the space behind the point of the projecting jetty; as soon as that occurred, the waves would no longer be arrested, but would travel up the harbour, as before the formation of the wave-trap.

If the effect of a wave, propagated by a steamer in a river, was observed, it would be found, that against the quay walls a sharp wave was created, whilst on the opposite side, if it was a sloping shore, only a gentle swell was formed. This was the action of the sloping beach in the wave-trap, upon which the force of the waves was gradually expended, and they were finally stopped by the jetty.

With reference to the groynes, it was very important to notice the specific gravity of the material collected. Fine sand was affected by the tidal currents; but the heavy shingle was affected solely by the wind-waves and swell. At Lowestoft, on one side of the harbour, there was fine sand, on the other side, shingle; the fine sand being affected by the currents, on the other, the shingle being affected only by the wind-waves.

The groynes on the Kentish coast would show, that nothing like a general rule could be laid down. When a heavy gale of wind was blowing dead off shore, a large quantity of shingle was accumulated, by the action of the lower part of the wave. Mr. Brunel's plan was very proper and safe on the south coast of Devon; but unless care was taken to record the character of the accumulation, no rule could be laid down.

It had been asked, whether, up to the present time, any certain results had been ascertained, as to whether the shingle was really accumulating; because such large masses of material were brought from the docks, that until that deposition had ceased, it would be impossible to tell whether, in the present instance, there was any actual accumulation from the sea. The proper time for ascertaining whether the groynes were really effective for accumulating shingle and sand, would be, when the deposition of material from the excavations for the Sunderland Docks had completely ceased.

Mr. CUBITT, *V.P.*, said, that previous to the formation of groynes on the South Rocks, there was not any tendency to deposit; but that the first timber groynes which had been laid down, close to the shore, showed that an accumulation might be encouraged with advantage: the more solid structures had, therefore, been adopted, not only to cause an accumulation of shingle and sand, but principally to

enable the material, excavated from the new docks, to be so deposited, as to form a permanent sloping beach, upon which the waves should break and roll along, carrying the surplus sand and shingle to form a deposit, eventually, along the south shore in Hendon Bay.

There was no subject so dependent on local circumstances as the position and direction of groynes: first, there was the strength of the tides and their direction with regard to the shore; and next, the prevailing winds must be considered, as, in his opinion, the wind-waves had more effect upon groynes than the tides; for, although the wash of the tide had a tendency to wear away the light soil of the coast, the wind-waves would frequently counteract the effect and restore the whole débris, although not in the same spot. These were circumstances which must determine the height, slope, and position of the groynes, as no rule could be laid down, except that an Engineer must be governed by observation and experience in similar cases.

With regard to the effect of the motion of the water, if the wind lay on shore, the surface of the water would move inwards, but the under current, caused by the reflux, would claw off the shingle into the deep water, whence it would be brought up again, by the reverse action of the under part of the waves, when the wind blew off shore. When the wind and the current acted in unison, a considerable accumulation would take place; but the whole might be carried away again under reversed circumstances. If, in a flood tide, the deposit was on the weather side, a corresponding excavation might be made on the lee side and *vice versâ*; but the object should be so to place the groynes as to prevent, to a great degree, the excavation under any circumstances.

Mr. J. Farey agreed, that there could not be any general rule on the subject. His late Father had, in his geological pursuits, studied very carefully the nature of the beach found on the coast, in the vicinity of strata which he examined for other purposes. The specific gravity of the material composing the beach should be particularly studied, because the same action of the sea, that would bring up light matters, would not act to the same extent upon heavy material: the bulk of the masses was also important. There was a total distinction between the beach composed of the flints from the chalk cliffs, which were sometimes so ragged and heavy, that they would not travel, and at other times were so round as to roll along with the least force,—and the beach formed by the débris, killas, &c. from the coast of Cornwall and Devon. The schistus at Whitby was another kind of beach, and the Chesil Bank was a remarkable instance of the power of the waves and littoral currents in forming

accumulations of transportable material. All those circumstances interfered with any general rule, as to the action of the water on the beach. The proportions of weight to space, and the looseness, or compactness of the beach, arising from the forms of the material, would much influence the tendency to travel under the action of given force. These points should be carefully observed, and the results would form a very interesting communication.

Mr. J. T. HARRISON observed, that one of the most interesting works executed on the South Devon coast, for the purpose of collecting the beach, might be called a wave-trap. At a point where a rock extended considerably outwards from the sea-wall, the waves ran along with great velocity and swept the shingle from the base, cutting down the foundation, which was in soft sand-stone rock, to such an extent as to endanger its stability. In order to accumulate the beach and to prevent the destruction of the wall, two small breakwaters of stone were erected, at some distance in front of the wall, and at an angle to each other, leaving a considerable space between them. As the waves came up, they struck against the breakwaters, were reflected and were broken up, so that the wave which passed in at the opening, spread itself out at the back and deposited the shingle, to such an extent, that in a short time a good gravel beach was formed, and there had been no injury done to the foundation, since the wave-trap had been formed.

The run of the tides produced very little effect upon the beaches at Dawlish and Teignmouth. The waves were the chief cause of the shingle shifting, and as the south-west was the prevailing wind, the waves raised by it drove the shingle along the coast to the eastward, causing an accumulation against the western side of the groynes, and, unless these were skilfully placed, laying bare the eastern side to the foundation, and causing a run along the wall, or coast they were intended to protect. The direction of the groynes should be at a considerable angle to that of the prevailing winds, so as to allow of the waves spreading out like a fan, and so depositing any shingle that might be carried with them. This direction was also advantageous when the wind was in the opposite direction, as it enabled it to act more powerfully on the accumulated shingle, and to carry it back along the coast.

Mr. REDMAN said, supposing the bays between the groynes at Sunderland to be entirely filled up with the excavated material and the deposited sand and shingle, would a permanent beach be formed? He thought that could scarcely be assumed until actual experience had shown what would occur, not only on the South Rocks, but also

with respect to the deposit of material near the intended entrance to the new docks, from Hendon Bay.

With regard to groynes generally, he thought the examples along the southern coast showed, that in many cases they were productive of quite as much harm as good. From Shingle End, near Ramsgate, to the South Foreland, there were, with slight exceptions, no groynes, and yet it was one of the finest beaches on the southern coast. On the Sussex coast there were numerous groynes, which, in many instances, cut up finely-formed natural bays, into a series of artificial bays, and were productive of forces which did not exist naturally. From Deal to the South Foreland the waves and the tide acted naturally upon the beach, producing an accumulation, and the beach remained more permanent than in many cases where groynes were erected. On the Sussex coast, which had been subject to great degradation, the shingle, notwithstanding the erection of groynes, was constantly travelling inland.

The absence of shingle at Dover, at the present time, was generally attributed to the falls of the chalk cliff, forming natural temporary groynes, and to the prolongation of a groyne at Folkestone, which was now creating a great alteration in the line of coast. Fifteen years ago, it was not an unusual thing for the fishermen at Folkestone to be obliged to dig out a channel, in the morning, to get their boats out, but there was, at present, a clear entrance.

April 3, 1849.

WILLIAM CUBITT, Vice-President, in the Chair.

The following Candidates were balloted for and duly elected:—William Brown Clegram, James Fenton, John Matthew, and William Radford, as Members; the Right Honourable the Earl of Lovelace, William George Armstrong, John Chubb, John Francis, Sören Hjorth, and William Piper, as Associates.

The discussion upon the Paper, No. 798, "Description of the Groynes, &c., at Sunderland," by Mr. W. Brown, being renewed, was extended to such a length as to preclude the reading of any other communication.

April 17, 1849.

ROBERT STEPHENSON, M.P., Vice-President, in the Chair.

No. 803.—"On the application of certain Liquid Hydrocarbons to Artificial Illumination: with a description of a new method of Gas-Lighting." By Charles Blachford Mansfield, B.A.

Among the numerous classes of substances, introduced by modern chemical researches, there is none, of which the members are so numerous, or united by such close links of relationship, as that of the hydrocarbons. The number of the combinations, which hydrogen forms with carbon, without the intervention of any other element, appears to be almost infinite; and although they are connected by certain marked attributes, which belong to them all in a greater, or less degree, their properties are very various. The characters, which may be predicated of them most generally, are inflammability and evaporability; but, in different species, the degree in which these properties are present is remarkably different. Oil of turpentine, naphthaline, marsh, and olefiant gases, caoutchouc, gutta-percha, the fetid oils of india-rubber, the perfumes of cedrat, of lemons, of orange-peel, mineral naphtha, wood tar, and, lastly, oil of coal tar, and coal naphtha, are some of the most commonly-known instances of this group, illustrating the variety which it comprises, and the diversity of powers, which rise out of the union of these two elements, hydrogen and carbon.

The object of the following Paper is to describe an attempt to extend the utility of certain of these substances, which, though elaborated in great abundance in Great Britain, seem not yet to have fulfilled all the purposes to which, by their nature, they are adapted. The branch of economy, which the Author has endeavoured to serve, is that of artificial light; and the property of these materials, of which he has sought to avail himself is that of volatility, in alliance with that which accompanies it, among these hydrocarbons, varying in direct proportion with the former,—inflammability.

Of these hydrocarbons, the greater number are liquids of moderate volatility: some, however, are gases at all common temperatures, to which the world is indebted for the present illumination of the streets; such also are the resin gas with which a part of Paris was, some time since, lighted, and the oil gas which was introduced in London many years ago. A few bodies of this class are known, which, being liquid at ordinary heats, pass into the gaseous state on a slight rise of temperature,—having, in fact, very low boiling points;

none, however, are at present manufactured, nor, it is believed, were any of them ever applied to use, except a volatile oil from caoutchouc, and a liquid obtained in the production of gas from oil, the commercial distillation of both of which substances has been long discontinued. The other liquids of this family which are most abundant, *e. g.*, oil of turpentine and common coal naphtha, enter into rapid evaporation only at temperatures above that, at which water boils; some of them, indeed, which form part of the 'heavy oil' of coal tar, requiring for their ebullition, temperatures not far below the boiling point of mercury. Others of the same group, which exist in various sorts of pitch, demand a heat, nearly amounting to redness, to volatilise them. All these substances, however, are in the true sense of the term, 'volatile oils;'—they are evaporable without decomposition.

Besides the gaseous hydrocarbons, which have been mentioned, some of these liquids have been used for the evolution of light. Coal naphtha is burned in lamps, with a broad flat wick, so contrived as to supply but a small quantity of the highly-carbonized liquid, and a large proportion of air to the points of combustion; but these are not in such common use as to be generally known. Every one, however, is acquainted with the beautiful light afforded by camphine, when burned in lamps of appropriate construction; and an oil distilled from the bituminous shale of Weymouth, promises to serve the same purpose. Recently, too, petroleum from a coal-mine near Alfreton, in Derbyshire, has yielded an oil which is said to burn brilliantly in common Argand lamps. In none of these instances, however, does the application depend on the volatibility of the material consumed; their liquidity is the essential point. Again, in the case of paraffine, (a solid wax-like hydrocarbon, which is reported to be obtained in such large quantities, by the distillation of Irish peat, as to be likely to become useful in the manufacture of candles,) its fusibility is the physical property which forms the ground of its adaptation.

But the tendency of liquid hydrocarbons to evaporate has not escaped application by the inventors of modern times. Now, the same difficulty here presented itself, which was combated in the camphine lamp,—that arising from the excess of carbon over hydrogen, which is found in all the common volatile oils.

Experiment seems to show, that the most perfect light is afforded, from wicks, or jets of ordinary arrangement, when an equal number of equivalents of carbon and of hydrogen enter into the composition of the material consumed. So that olefiant gas ($C_4 H_4$), one atom of which consists of four atoms of carbon and four of hydrogen, may

be considered as the typical light-fuel. As the proportion of these elements recedes from this standard, the value of the compound as a common source of light decreases. Thus marsh gas ($C H_2$), whose presence as a diluent in coal gas impairs the luminosity of its flame, alcohol ($C_4 H_6 O_2$), and wood spirit ($C_2 H_4 O_2$), in all of which substances hydrogen predominates, burn in the open air with a pale flame, yellowish, or blue; whilst, on the other hand, the flame, which is obtained, under similar conditions, from oil of turpentine ($C_{10} H_8$), from naphthaline ($C_{10} H_4$), and from coal naphtha, in each of which the proportion is increased in favour of carbon, is reddish and sooty, evolving clouds of smoke.

Here, then, was the obstacle to be surmounted in the application of these latter materials, and when it was removed, not only was a negative inconvenience disposed of, but there resulted a positive gain, for the whole of the redundant carbon was, of course, available as luminous matter; carbon being, emphatically, the source of terrestrial light. Perhaps, in fact, the amount of this element in any substance may form a sort of measure of its luminiferous capabilities, when placed in the conditions appropriate to their development;* though, perhaps, for the two values, the ratio of progression is not actually the same.

Two methods, of attaining the desired end presented themselves: one, that of causing the richly-carbonized vapour of the volatile oil to mix itself so completely, with a sufficient quantity of air, that the whole of the carbon may, after suffering the requisite incandescence, be effectually oxidized: the other, that of mixing the vapours with other combustible vapours, or gases, containing less of the smoke-forming ingredient. The first of these designs was accomplished by supplying with the volatile liquid, under pressure, a burner having a very small jet-hole: this being heated, some of the fuel is converted into vapour, and rushing through the minute perforation, with great velocity, into the air, is burned with a perfectly white flame, which, continually restoring heat to the burner, supplies itself with a regular flow of gaseous fuel. Many forms of burner have been proposed for these lamps, and some recent improvements in their construction are bringing them now into more extensive use.† This ingenious contrivance gives a splendid light, but the rush of the vapours through so small an aperture, creates a noise, which, with

* In the 'voltaic arc,' extended between charcoal electrodes, is seen the maximum effect evolved from uncombined, undiluted, carbon.

† Patent granted, January 5th, 1848, to Mr. Read Holliday, of Huddersfield, for "improvements in lamps."

the necessary proximity of the inflammable liquid to the flame, may perhaps exclude it from adoption in dwelling-rooms, but do not, in the least, diminish its utility in out-door premises.

The other method of diminishing the carbon in a flame supplied by these substances,—that of mixing their vapours with other gases, has been contrived in different ways.* Of one of these the Author has availed himself, in charging a lamp with a mixture of pyroxylic spirit and a very volatile hydrocarbon procured from coal tar. The principle, on which the fuel of this lamp is made, not having been hitherto applied successfully in this country, he was not aware, till after the perfection of his contrivance, that lamps supplied by an analogous method, had been, for some time, in use in other parts of Europe and in America. The material consumed abroad, however, although prepared on the same principle, is not the same as that used by the Author. In these countries, oil of turpentine, which is heavily charged with carbon, is dissolved in alcohol, (the mixture being called 'gazogène,' in Paris,) for use in these lamps, which in Germany are known as Lüdersdorff's. In England, where, for all really useful purposes, alcohol is too dear to be consumed, especially as a fuel, such a material would be inapplicable, even if only moderately strong spirit were requisite; but, to dissolve a sufficiency of oil of turpentine, alcohol of so high a degree of purity is requisite, as to be quite beyond the means of an economical people. In this country, wood spirit now affords a cheap substitute for alcohol, and coal naphtha, or some of its hydrocarbons, supplies a less expensive material than camphine. Such a mixture, (of two parts of spirit with one part of naphtha,) which is conveniently used as fuel for portable gas-lamps, can be made for four shillings and sixpence per gallon: and not only have these latter hydrocarbons a commercial, but also a chemical advantage over that distilled from turpentine, for they are far more easily soluble in wood spirit than is camphine. Attempts have already been made to introduce into use in England a solution of volatile oils in wood spirit; but certain difficulties seem to have attended the preparation of the mixture, which later improvements in the manufacture of the materials have removed.† If, in

* Patent granted, November 11th, 1849, to C. B. Mansfield, for "An improvement in the manufacture and purification of spirituous substances and oils, applicable to the purposes of artificial light, &c." Sealed, November 11th, 1847, Enrolment Office, May 8th, 1848.

† *E. g.* patent granted, April 27th, 1841, to André Dronot de Charlieu, for "Improvements in preparing matter to be consumed in obtaining light, and in the construction of burners for burning the same."

such a mixture, the proportion of the oil is smaller than that above described, it will yield a flame below the maximum in luminosity, while, if it is poor in spirit, it will have a tendency to evolve smoke when ignited.

The dilution of the hydrocarbon vapours may also be effected by mixing them, before their arrival at the point of combustion, with permanent gases, inflammable, or non-inflammable; in which case the flame will be supplied with a mixture of airs, or gases of inferior, or of no illuminating power, and vapours having more than a sufficiency of the light-giving material. This method may, therefore, be defined either as a process of reduction of the exuberant carbon of the one, or of enriching, with luminiferous matter, the other ingredient of the mixture, and the name which the application would obtain, would probably express the one, or the other notion, according to the road by which the invention was reached;—according as the object sought was to increase the utility of the liquid hydrocarbon, or to enhance the services performed by the gas.

Now, the latter of these was the aim of the contrivance, by which this theoretical adaptation has become, in practice, known to the public; and hence the technical term,—'naphthalization of gas.' However, the principle, on which this plan is founded, might with equal propriety, claim the appellation,—'gasization of naphtha.' And this may be well illustrated by a brief historical sketch of the order in time, through which this form of application has progressed. The Author hopes it will be perfectly understood, that he does not represent the later of these inventions as a necessary consequence flowing out of the earlier, nor as in any way consciously derived from them; they simply show the successive results, in one small field, of the progressive strife of the human working faculty with the material world, which is continually challenging it to conquest. For the history of science seems almost to establish it as a law, (which can agree but ill with patent-right,) that all revelations of physical truth, and of its applications, are made simultaneously through a plurality of intellects; and, that progressive expansions of any one conception should take place independently in different minds, is but an extension of the same expression. In confirmation of this, the Author may state, that, previously to his having been led to the invention, which he wishes now to present as a farther development of the naphthalizing principle, he was unacquainted with any of the contrivances, which he will first describe as introductory to his own.

The following notices, then, may be interesting in this point of

view: they are not offered as a complete account, but as the result of desultory glances at some catalogues of patents.

The first hint of the naphthalization of gas, or gasization of naphtha, which the Author has met with, is in the specification of Donovan's patent* (1830): in this it was proposed to render luminiferous, (or "luminous," as it is inaccurately expressed in that document,) "certain gases, which, although they burn, do so with emission of very little light, such as hydrogen, carbonic oxide, or the gases produced by passing steam over ignited coke." The mode described is that of bringing them into contact with surfaces "of oil, or spirit distilled from vegetable tar, from rosin, or from coal tar, or of naphthaline dissolved in these liquids." The inventor remarks, that different arrangements will be required, according to the volatility of the hydrocarbon applied: he describes certain modifications of the reservoir, in which the oil is to be converted into vapour, and of which the form, position, and proximity to the burner must vary, according to the nature of its contents. The case chiefly designed is, evidently, that of a liquid requiring the assistance of a high temperature for its evaporation; for the appliances, which are most carefully detailed, are those of a vessel, close to the gas-burner, and containing an arrangement of fine wire, which exposes, and at the same time conveys heat to, a large surface of the oil, over which the stream of gas is made to pass. Mr. Donovan, however, also states that, when the naphtha used is so volatile as to mix with the gas, at the ordinary temperature of the air, the burner need not be immediately in contact with the reservoir, but that a tube, even six feet in length, may be interposed between the "recipient" and the flame. But he does not farther describe such an arrangement: contenting himself with stating, that "coal naphtha by repeated distillation may be rendered so specifically light, that it will be converted into vapour at the ordinary temperature of the atmosphere." Now this is not correct: for if coal naphtha is distilled and re-distilled for ever, neither its specific gravity, nor its volatility, will be, in the least, diminished, or increased; neither, if its specific gravity could be lessened, would it follow as a consequence, that its volatility should be, in any degree, enhanced. A highly-volatile liquid can be separated from coal naphtha, or other mixed naphthas, by distillation, only by reserving apart a first fraction of the product received, which will be more volatile, while the latter portions will be, correspondingly, less volatile than the original liquid. In fact, at the period

* Granted, October 6th, 1830, to Michael Donovan, of Dublin, for "an improved method of lighting places with gas."

of this invention, and, indeed, until very recently, no liquid hydrocarbons were known to be cheaply procurable, in quantity sufficient to enable it to be practically applied, in any but its more clumsy, and therefore objectionable, forms. It is believed, that this proposition was never carried into useful effect. The obstacles to its adoption probably lay in the necessary multiplication of the reservoirs, and complication of the burners, involved by the only materials then available for the naphthalization of the particular class of gases, of which it occurred to this inventor to avail himself. Mr. Donovan expresses the essential point of his project, as being a method of lighting places with gas, by mixing the vapour of any of the volatile combustible oils with any of the "inflammable but non-luminous" gases. It will be remarked, that this patent, having for its object the profitable application both of the liquids and of the gases, alike, rested equally upon both poles of the axis, on which the principle, which is here considered, turns. The Author of the present Paper has given an extended analysis of this proposal, because the details will spare description in the subsequent survey of parallel contrivances, and because it approaches, perhaps, in intention, more closely to his own than either of those which follow.

The next development of the principle appears in the embryo of Mr. Lowe's invention, to which allusion has already been made. In the specification of a patent granted to him in 1832,* this gentleman proposed to increase the value of common coal gas, as an illuminating agent, by passing it through naphtha, or other hydrocarbonaceous liquids, contained, instead of water, in a gas-meter.

Shortly after the publication of this proposal, another scheme arose, (in 1834,) which must be classified as a species of this genus of application. This invention of Mr. Beale afforded material for two patents. The design of the first of these,† was to burn "mineral naphtha, coal naphtha, animal oil, or oils distilled from caoutchouc, wood-tar, or resin." And this was to be effected in lamps of two, or three sorts; in one of these, a blast of atmospheric air was driven through a flame, kindled on the surface of the liquid hydrocarbon, in a small open reservoir. In this arrangement, the air served only the purpose of a blowpipe blast, not being mixed with the vapour,

* For "increasing the illuminating power of such coal-gas as is usually produced in gas-works." Sealed, June 9th, 1832.

† Patent granted, January 4th, 1834, to J. T. Beale, of Whitechapel, for "a lamp applicable to the burning of substances, not hitherto burned in such vessels, or apparatus."

before reaching the flame. But in another, described in the same specification, an air current was passed through a vessel, in which, at the base of a table-lamp, naphtha was kept boiling by a small lamp beneath, while the mixed air and vapour ascended to the burner above.

There may not, at first sight, seem to be much in common between this invention and that of Mr. Lowe, but in the latter of Mr. Beale's lamps, the principle involved is the same as that of which Mr. Lowe avails himself;—the evaporation of the naphtha into an atmosphere of another gas. The difference consists in this, that Mr. Beale's gas, containing no luminiferous material, requires a larger quantity of carbon to be supplied to it, in the form of vapour, than does the coal gas, and this requisite is supplied by the additional provision of heat. And, perhaps, in Mr. Lowe's case, the chemical affinity, (the word is here used in its real sense of family relationship, not of conjugal attachment of opposite qualities,) between the liquid hydrocarbon and its gaseous congener, exerts an impulse to evaporation, which, being absent in atmospheric air, must be replaced by a certain expenditure of caloric force.

The second patent of Mr. Beale,* (1837,) was the next outgrowth of this branch of ingenuity. In the specification of this, he describes some improvements on his original lamps, and a new adaptation of the same principle. In the new lamp, he employed a reservoir of the volatile liquid, close to the burner, (as was proposed by Donovan); the gas, or air stream, passing into this vessel, comes into immediate contact with the metal of the burner, so as to be heated, when the lamp is once kindled, and to be enabled to take up the vapour of the oil. The burner is also adapted, if necessary, to heat the liquid by direct metallic contact, thus supplying the place of the heater-lamp in the former invention. He now proposes to send "air, or gas, or a mixture of these," through the pipes which supply his apparatus. The object of his contrivance is, clearly, the profitable consumption of the liquids, not the improvement of the aeriform fluids which he uses, so that, being as it were, polar to the invention of Mr. Lowe, it would come under the converse term,—'gasization of naphtha.' The purchasers, however, of this invention, which, it is believed, is called 'the air light,' have not succeeded in making it profitable either to themselves, or to the public. The impediments to its use were, probably, the same as those which interfered with the successful application of Donovan's plan, for the scheme must

* Sealed, December 7th, 1837, for "certain improvements in, and additions to, his former invention, known by the title of—'For a lamp, &c.'"

have presented itself, either as a system of gas-lighting with complicated lamps instead of simple burners, or as an arrangement of ordinary lamps with the additional machinery of pipes, and of power for maintaining the flow of air, so that it was not more likely to attract a critical public, than one which was subsequently suggested,* for supplying a blast of air, from a blower, or reservoir, to the interior channel of common Argand lamps, for the purpose of improving their light.

The next attempt to turn the services of liquid hydrocarbons to account, in this direction, appears, (among some other inventions connected with gas-making,) under a second patent † of Mr. Lowe, (1841,) according to which he "claims" "the application of sponge, or other suitable material, and the use of shallow trays charged with naphtha, and other volatile hydrocarbonaceous liquids, for increasing the illuminating power of coal gas." And this purpose he fulfils, by passing the gas over, or through, such an apparatus on its passage to the ordinary burners. The aim of this invention is thus defined, as the exaltation of the qualities of the gas; Mr. Lowe, in this case, resting chiefly upon one pole of the principle,—the opposite to that which supported Mr. Beale,—restricting, too, his reliance there within the limits of coal gas. In the instance of this application, the advantages of which are so obvious, it is difficult to discover what physical obstacle can have so impeded its earlier introduction, nevertheless there must have been such obstacles, for its proprietor sought, and obtained, an extension ‡ of the privilege conferred by his first patent.

Now this might seem to be the culmination of naphtha in this particular orbit of utility: and so it might have been, had the composition of coal naphtha not been subjected to further scrutiny. But it has recently been ascertained by some experiments, which have been already published, § that common coal naphtha consists of a series of definite liquids of various degrees of volatility, one of which,—benzole,—is so volatile, that a stream of atmospheric air, of the ordinary temperature, passing over it, will take up so much of its vapour, that the mixture will burn with a white flame. This tendency to evaporate, places it on the same footing with re-

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* Patent granted, May 7th, 1841, to G. Halpin, of Dublin, for "improvements in applying air to lamps."

† For "improved methods of supplying gas under certain circumstances, and of improving its purity and illuminating power." Sealed, March 16th, 1841

‡ For five years. Sealed, June 4th, 1846.

§ *Vide* "Quarterly Journal of the Chemical Society," vol. i. p. 239.

gard to common air, as that on which common naphthas stand with respect to coal gas.

This highly-volatile oil, or spirit may be rectified from the less evaporable oils, with which it is mixed in the coal tar, or coal naphtha, by any of the stills used in the rectification of alcohol. There is, however, a difference in the two cases, which renders the extrication of the benzole easier than that of the alcohol. The boiling point of the two is the same, viz. 80° Centigrade, (176° Fahr.): but the spirit of wine has to be distilled out of an aqueous mixture, of which the water boils at 100° C. (212° Fahr.); while the benzole is diluted in the crude light naphtha, with other oils of various boiling points far higher than its own, up to 200° C.(392° Fahr.), and that which comes next to it in the scale,—toluole = $C_{14}H_8$,—boils at about 113° C. (235° Fahr.); so that the interval of temperature is far wider, and therefore more favourable for rectification. And not only is there this advantage, but the fortunate intervention of the boiling point of water, between those of the oils, here mentioned, very much facilitates the operation, if conducted in a proper still, made expressly for the purpose.

An apparatus of this kind, which the Author used with great advantage, simply consists in an ordinary still, the head of which is raised to the height of the oscillatory vessel itself. This head is surrounded by a second vessel, which may be filled with water, for the purpose of cooling the vapour rising in the head. It is, moreover, provided with a secondary neck, which traverses the water vessel very near the bottom, and which may be closed and opened at will.

When heat is applied to the retort, or still, all the condensible vapours, if the water in the cooling vessel is cold, are stopped in the head, and are returned to the retort: this will continue, till the water in the cooling vessel is so far warmed by the process, as to permit the escape of the vapour of the most volatile of the naphtha oils, through the upper neck, while it will continue to condense, almost entirely, the liquids having higher boiling points than its own, which will be returned to the retort, or may be collected in a separate receiver placed in ait-tight connection with the secondary neck, at the bottom of the cooling vessel. This process will continue,—the benzole vapour meantime passing over, and being condensed by the cold water surrounding the head of the still,—till the whole of the hydrocarbon is separated. The temperature of the water in the cooling vessel will continue to rise till it reaches the boiling point; and when this takes place, if the proportions of the parts are properly adjusted, distillation will have ceased altogether, and will not be

resumed till the water in the cooling-vessel is nearly all evaporated, or till the secondary neck is opened.*

The perfection of the rectification will, of course, depend on the extent of surface of the head exposed to the cooling influence of the water in the vessel surrounding it, and on the correspondingly rapid reduction to the liquid state of the more condensible vapours. The product of this distillation is fit for use, after being subjected, as it distils, to a simple chemical treatment, which consists in passing the vapour, or the liquid as it condenses, through a vessel charged with sulphuric acid, or other appropriate agent.

The discoveries of the methods previously mentioned, of making liquid hydrocarbons a means of gas-light, were limited in their endeavours, by the want of a naphtha of sufficient volatility. The Author believes, that the problem, towards which their designs were tending, has been solved by the appearance of this spirituous hydrocarbon,—benzole.

In bringing forward a new mode of lighting, presenting, as he believes, all the advantages and none of the disadvantages of coal-gas illumination, the inventor does not suppose, that his system can compete with gas for general purposes, in any district where gas is already established, and reasonably cheap;—besides it might be convenient to the manufacturer of benzole, to remain, as at present, dependent on the gas-works for the tar which yields his material;—but he believes that, in places where coals and gas are dear, or where gas is considered objectionable, or is inapplicable, his method will not only answer every purpose of gas, at a very cheap rate, but

* The rectification of the residual naphtha may, however, be more effectually conducted through the head, than through the secondary neck, if either the top of the cooling vessel is made so as to be closed, at will, by a valve, thus putting pressure on the steam evolved and allowing the temperature of the vessel to rise. This same end may, of course, be attained without the inconvenience of high pressure, by drawing off the water, and substituting for it, either a solution having a higher boiling point, or a fixed oil. Or this may be done with greater nicety and economy, by charging the cooling vessel with coal naphtha, and connecting it with another condensing apparatus; in which case, by the same consumption of fuel, a secondary distillation will be effected, which may be continued up to any required point, at which the temperature may be arrested and kept constant for any length of time. The means by which this latter object is effected, is by a contrivance of the Author's, called an 'isothermal bath, or oven,' which is described in the "Mechanics' Magazine," No. 1,296, p. 559, and in the "Pharmaceutical Journal," vol. viii. p. 38. Its object,—that of maintaining an unvarying temperature,—is similar to that of the 'thermostat,' described hereafter in this Paper; but the principle is altogether different, being only suited to a higher range of temperature, commencing with the boiling point of a very volatile liquid.

will far excel that product in many points of utility; so that it may take its stand as a fitting supplement to the existing plans of gas-lighting. The purity and whiteness of the light, obtained by the means which he proposes, cannot be questioned: and a simple statement of its cost will give the means of judging of its economical advantages. Unskilled in engineering, he is prepared to meet with some difficulties in the practical application, on an extensive scale, of a system which is simple and easy in the small model form in which he is able to exhibit it: yet he cannot believe, that any obstacles will present themselves, which a few experiments will not surmount.

The method of application is simply this: a stream of gas, (not oxygen, or such gases as are prejudicial to health,) is conducted through a reservoir charged with a hydrocarbonaceous liquid. This substance must have two properties: first, such volatility as to yield a large quantity of vapour to the current of air, and, secondly, so large a proportion of carbon in its composition, that if burned in free mixture with the air, its flame will be luminous. The liquid, which is here employed,—benzole,—which has, besides, many other remarkable properties that confer on it a high chemical interest, as well as practical value for various uses in the arts, combines these two requisites in a great degree of perfection. The boiling point,—the same as that of spirit of wine,—indicates its strong volatility, which, however, is not so extreme as to make it unmanageable: while the excess of carbon which it contains, ($C_{12}H_6$,)—shown by the volumes of smoke, which it evolves, when burned in the open air,—insures a sufficiency of luminiferous matter in the vapour.

It will be evident, that this principle is not exclusively fitted for application on any particular scale of magnitude; but that, if suited to the dimensions of gas-works, it is no less adaptable to the compass of a table-lamp. The Author, in his specification, has suggested the concentration of the whole organism into the body of a lamp: clock-work and a revolving-blower are the most obvious means. One form may be here mentioned, (since it involves a new contrivance,) in which the flame, by the draught of its own chimney, supplies itself, without mechanism, with vaporized air, by sucking it through the reservoir. Whatever may be its capability of being applied in a more ambitious form, that may bring the scheme within the cognizance of engineering science, it is only as a system of ramified illumination, not as a contribution to lamp-making, that the Author wishes to represent his plan at present. It is, then, to the development of the principle on the extended scale, that he will here confine his description.

In the apparatus here arranged, this liquid,—benzole,—is used to 'naphthalize' a supply of common atmospheric air, as it flows from a small gas-holder, which is filled by a pair of bellows. Hydrogen, or carbonic oxide, or mixtures of these with coal gas, might be used with equal, or, in some circumstances, perhaps, with greater convenience, as the vehicle of the light fuel. The gas, or air, consumed in this arrangement, may be considered as a fluid wick permeating the pipes, to bring the liquid to the point of combustion. Whether gas, or common air, were resorted to for this purpose, would, in practice, depend on the relative price, or local convenience of chemical and mechanical force.

If, however, pure oxygen is driven through the reservoir, it forms with the vapour, which it takes up, a mixture, which, on ignition, will explode with enormous energy. Oxygen, then, applied in this way, is not suited to aid the volatile hydrocarbon in affording light; for, even when effected at a safety-tube, the combustion is so rapid, as to yield only a small non-luminous flame. It is, however, certain, that such a mixture of oxygen with the vapour of benzole, or of other inflammable liquids, might be made a source of vast mechanical power for blasting, or for the projection of missiles: perhaps indeed, the convulsive force might be converted into a continuous one in an engine, in which intermittent explosions of the gas might be induced by a small voltaic battery, the mechanism itself pumping its charges of gas through the vapour-vessel, and alternating the contacts of the conductors. It is probable too, that considerable power, for these purposes, might be obtained, by similarly igniting a properly-adjusted mixture of common air with the vapour. But, and this is essentially fortunate for its application to lighting, there is some difficulty in making an explosive mixture of benzole vapours with air. For this end they must be far more abundantly diluted with air, than happens when they are passed in a stream through the liquid: for the air takes up more than it can itself consume, and the proportions must be nicely adjusted, for the limits are narrow, within which they are capable of simultaneous and unassisted combustion. However, with a less volatile hydrocarbon, or with benzole kept at a very low temperature, common air, by simply passing over it, may be readily 'vaporized,' just so as, on ignition, to take fire throughout. The mixture approaches this state when, on being inflamed, as it slowly escapes from a moderately large jet, it yields a cone of pale-blue light, not streaked, or tipped with white,—a very useful flame, where great heat is required in a small compass.

But oxygen may be adapted to this contrivance, so as to yield a

light rivalled in splendour only by the voltaic arc, or by the Drummond line-light. If hydrogen, or any other similarly combustible gas, is made the vehicle of the hydrocarbonaceous vapour, and is consumed at a burner to which oxygen is supplied by a separate tube, a flame may be produced, perhaps the most beautiful that can be obtained. This may be conveniently attained, by decomposing water by a voltaic pile, and by passing the hydrogen through benzole, and thence to the jet, to which the oxygen is directed through another channel. An arrangement of this kind, in which coal gas dosed with a common naphtha, was burned with oxygen, was recently exhibited by Mr. Brande,* who stated his belief, that it would be the best light that would be conferred by cheap electricity:—but the greater volatility of, and the larger amount of carbon in, benzole, would place it as a contributor to this valuable effect, far above any hitherto known liquid.

Returning now to the main subject:—in the system of gas-lighting proposed by the Author, neither furnaces, retorts, coolers, purifiers, nor meters are required,—the burners yield products of combustion, as harmless as those evolved from the purest wax,—and in the process not a particle of coke, of tar, of dirt, or of residue of any kind is produced. Such are the characters which encourage him to hope for its introduction into libraries, drawing-rooms, and boudoirs, where London gas has failed to find admission,—into theatres, country mansions, and factories, where independence of external supply may be requisite,—into churches, light-houses, and railway stations, where gas-works may be inconvenient,—and into ships, and especially into ocean steam-vessels, where it would be difficult to introduce them.

The Author having stated what his method does not require, must place in the balance, the conditions which are essential to its success. The requisite appliances are, first, as for coal gas, an arrangement of pipes and simple burners; secondly, a reservoir of the volatile fuel; and, thirdly, an arrangement for supplying a constant current of gas, or of air. The power which impels the flow of aeriform fluid, may be derived,—either from its expansion as it is generated, according to any fit methods of chemical decomposition, of which, perhaps, none would be cheaper than that of passing steam over ignited coke;—or from some form of mechanism, which would be chosen according to the extent, to which the system was to be worked. If the system were adopted on a large scale, a stream

* At the Royal Institution, February 2nd, 1849. *Vide* "Chemical Times," vol. iv. p. 187.

of air might be obtained from gas-holders, raised by the introduction into them of steam directly from a boiler, without the intervention of any machinery: the atmosphere being admitted, to condense and replace the steam, when the vessels had risen to their full height. Perhaps this method would be impossible, or, if possible, may not be new; but it appears to the Author to be, if practicable, as simple as any that could be devised for the purpose. In a steam-ship, or factory, where power is at hand, of course this heart of the circulation might be, most conveniently, formed as a small pump, or bellows constantly working into a small air-bell, or gas-holder. In country mansions, railway stations, and churches, a weight, wound up by manual labour, would form a reservoir of force for the supply of a similar mechanism; and the expenditure of its power might be regulated and economized by the gas-holder itself, which might stop the descent of the weight by a detent, when it should become nearly full, and release it again as soon as the charge required to be renewed. For separate dwelling-houses in towns well supplied with water, the moving power might be communicated to the blowing apparatus, by a cylinder and piston worked by water-pressure.

The next requisite is, that the arteries, conveying the steam, should not be exposed to a very low temperature. The reservoir of liquid must be in a moderately warm place, so that no check be given to the evolution of gas, which takes place with ample rapidity, at the average temperature of our climate. Since, however, the formation of the vapour will be continually abstracting heat from the liquid itself, it is requisite to supply the vessel with as much caloric as is carried off by this process. This may be conveniently adjusted in a variety of ways, most simply, perhaps, by causing a small burner, forming part of the system itself, to play upon the reservoir, or upon a vessel of water in which it may be immersed, or upon the pipe by which the air enters it.

However, this will not insure perfect uniformity in the evolution of vapour, if the number of burners in use is liable to variation. For, the cooling of the reservoir by evaporation, at any moment, is immediately dependent on the quantity of light required, and on the number of burners employed: if, therefore, this varies, while the warmth supplied to the reservoir remains constant, the temperature of the liquid, and consequently, the degree of impregnation of the air with vapour, will be changed. For instance, supposing a flame of given size to compensate exactly the cooling due to the supply of one hundred burners, if fifty of them were turned off, the reservoir would become warmer, and the remaining fifty would be liable to

smoke, or would require adjustment to bring up the quality of their light to the original standard.

It was, therefore, desirable to devise a means of preventing the temperature of this vessel from being raised by its jet, above the required point, which, for benzole, is about 17°, or 20° Centigrade, (63°, or 68° Fahr.). This is effected by a simple instrument, which may be called a 'thermostat,' the principle of which is equally applicable in other cases, where a constant temperature is requisite. Such a contrivance consists in the metallic evaporating vessel, to which one of the well-known arrangements supplies the liquid at a constant level. The vessel is, moreover, provided with one tube, through which the air enters, and another through which it escapes, charged with vapour, to the burners; from the latter tube, a short pipe branches off, terminating in a small jet directed towards the side wall of the evaporating vessel. The evaporating vessel is provided with a tube in the form of a syphon, partly filled with mercury, the closed limb of which, terminating in a bulb and containing, over the mercury, air and some ether, or other sufficiently volatile liquid, is within the reservoir, while the other, open at the end, is without the evaporating vessel. On the mercury, in this open outer limb, floats a light rod of wood, cane, or cork, to the top of which, by means of a wire, is attached a screen of talc, or other light fire-proof material, which when slightly raised, intercepts the flame of the small jet and prevents its approaching the metal of the evaporating vessel.

The use of the ether is to add, by its vapour, to the effect of the expansion of the air in the bulb, when its temperature is raised. Now, whenever the heat supplied from the little flame exceeds that carried off by the evaporation of the benzole, the expansion of the air and ether-vapour in the terminal bulb, will depress the mercury in the inner limb of the syphon, and raise it in the outer one. But with the mercury level in this outer tube, the rod and its screen rise, and thus the influx of heat from the flame is shut off. The rise of temperature is then arrested, till the evaporation again cools and contracts the atmosphere in the bulb; the mercury then retreats, the screen falls, and the vessel is again exposed to the flame. The temperature is thus self-regulating, and the supply of vapour is exactly adjusted to the varying requirements of the system.

The same end may be contrived in other ways; for instance, by causing a movement of the screen, or of the jet itself, to be effected by the bending of a compound blade of two metals of dissimilar expansive tendency, such as platinum and silver.

If the light is not required to be absolutely constant for a long time, no such precaution is necessary; if it is omitted, a slight

gradual diminution of the size of the flames will, after some time, be perceptible. But if a much larger supply of the liquid is placed in the reservoir than is required for immediate consumption, this effect may be diminished to any required extent, for, of course, the cooling of the substance in the vessel will be inversely proportionate to its mass. The Author has found, that the evaporation into a current of atmospheric air of the temperature of 17° Centigrade, (63° Fahr.,) of one ounce by measure, of benzole, from eighteen ounces, reduces the remaining seventeen ounces from 17° C. to 14° C. (63° to 57° Fahr.); while an equal abstraction of one ounce from three ounces of the same liquid, in the same conditions, brings down the temperature of the residual two ounces to 10° C. (50° Fahr.*); and two ounces subjected to the same treatment, fell from 17° C. to 5° C. (41° Fahr.). In the third case, the thermometer index fell in five minutes, and in the second case in ten minutes, through the first 3° Centigrade, (5½° Fahr.), which, in the first experiment, it took seventy minutes to traverse. In the third instance, the flame at the jet had become entirely blue, after the first fifteen minutes; but in the first case, the brilliancy and size of the white light were scarcely perceptibly diminished, at the expiration of an hour.

As for the burners, if atmospheric air is the vehicle of the vapour, the jet holes must be slightly larger than those for the consumption of coal gas, as will be evident from the consideration, that a part only of the aeriform fluid issuing from them is electro-positive in the combustion. Some burners, which the Author has contrived for the ignition of 'naphthalized' air, have been found to perfectly answer this purpose. They are constructed, so that the size of the orifices, from which the gas escapes, may be adjusted with the greatest nicety, and thus insure the most perfect combustion.

It will be seen, that the quality of the flame obtained from gas, issuing from an aperture, depends upon two quantities; first, on the amount of luminiferous matter present in the gas; secondly, on the velocity with which it escapes from the jet, which velocity is, of course, a function of the size of the jet, and of the pressure which urges the flow. For on the manner of this escape depends the more, or less complete mixture of the gas with the surrounding air. If this mixture is insufficient, smoke will be formed; if it is too rapid, the carbon is instantaneously burned, and the flame is, therefore, devoid of luminosity. Hence, if a certain definite quality of flame is required, from gas of a given quality, under a given pres-

* Perhaps these rough experiments may suggest a method of deducing the specific heat of the vapours of volatile liquids.

sure, at a jet of a given form, without a chimney, or with one of given dimensions, it can only be attained by assigning one definite value to the only remaining variable, viz., to the size of the jet. And if, 'cæteris paribus,' either of those factors, whose constancy is not under the control of the consumer, should vary, the alteration, in the resultant light, can, in no way, be compensated more readily, than by a corresponding change of this condition of the burner.

Now the principle of these burners is applicable to jets of almost any shape, and it not only gives the means of insuring the most perfect luminosity that any sort of gas can yield, but also of producing a flame of any character that may be required, whether for light, or for heat. The almost lightless blue flame, ensuing from the rapid combustion induced by narrowing the jet aperture, affords a great heat, which is well adapted for the kitchen, or for the laboratory. Burners formed in this manner, would have the additional advantage in application to coal gas, that the jets may be easily cleaned within, from time to time, from the deposit which frequently clogs the minute apertures, or tubes, at which gas, containing ammonia, and other impurities, is burned. The mechanical means which suggest themselves for the variation of the size of the jets, are very numerous, and need not be here discussed.

The Author has now described the general principles of his system; it remains for him to mention some variations, of which it will admit, in application. These are chiefly in the position and adjustment of the reservoir of liquid. The entering-pipe may be made to dip simply into the liquid, which is a very convenient mode for thoroughly charging the air with vapour, though, of course, it neutralizes a certain amount of the pressure exerted for the propulsion of the stream. The reservoir may be fitted with a fountain for maintaining a constant liquid level, or it may simply consist of a bottle. In practice on the large scale, it might be found convenient to use a rather more complex organism to vitalise the circulating fluid; for instance, the liquid might be made to fall in a continual shower through the volatilizing chamber, which again, might be supplied with sponges, cotton, or pumice-stone, to increase the surface for evaporation.

The reservoir would, of course, be made of strong metal, and would have no communication, from its interior, with the air surrounding it, except through the small jet for regulating the temperature. There could not arise any danger in any dwelling-house, from the presence of such a vessel of the inflammable material.

It will be evident that, if a liquid volatilizes, without the neces-

sity of heat, into an atmosphere which is not subsequently changed, or mixed with any other substance, and if this atmosphere moves through vessels, or pipes, which are not cooled below the original temperature of evaporation, there will be no tendency to the deposition of the vapour. Neither will this take place, even if the pipes are colder than the liquid, until the cooling reaches the benzole dew-point of the enclosed atmosphere, which, (since the air in its rapid passage is not likely to have been perfectly saturated with the vapour,) will, probably, be some degrees below the temperature of the reservoir. It might, however, be found useful to jacket these tubes, where they were exposed to cold. It has not been found, that the intervention of any length that has been hitherto tried, of brass pipe between the fuel-store and the flame, causes any alteration in the quality of the light; and, with reasonable precautions, the ramifications of these pipes, or wick-channels may, doubtless, be lengthened to an indefinite extent. It is possible, that square miles might thus be lighted from one central establishment containing the naphtha fountain, as well as the air-power; but this can only be tested by actual application. However, without the slightest doubt, a system of illumination of any magnitude, (*i. e.*, limited only by the resistance of the pipes to the air-current,) might be conducted, if the reservoirs were placed at intervals along the arterial mains. For external lamps, in very cold situations, it might be found useful to have a small reservoir within the lantern of every burner. For large separate buildings, or for steam-ships, the whole application is so simple, that it is needless to dwell on its facility; a single hydrocarbon fountain, with pipes all placed in moderately-warm situations, and a quarter of an hour's work per diem, of an able-bodied man, or a constant tax of a few ounces on the power of the available engines, for the air-pump, are all the conditions that would be required.

But in towns the plan will admit of an arrangement, which would offer great conveniences. Let it be supposed, that a company undertook to light districts with 'benzole gas,' or 'naphthalized air.' They would agree with the consumers, whom they supplied with pipes and air, that the hydrocarbon for their private reservoirs should be purchased of the company alone: they might then station their works, put up their pumps, and lay down their mains and pipes. Every householder may be provided with a separate fountain, through which alone the tubes enter his premises, and which may be closed under the company's lock and seal. This vessel will then be the exact measure of the extent to which the consumer has drawn upon the resources of the enterprise, both in hydrocarbon and in air; and

will form a perfect meter for the regulation of payments. It may be fixed, of course, in the cellar, or in any convenient place, where the conditions, before mentioned as requisite, may be secured.

After indulging so much in speculation, a few facts may fairly be demanded of the Author, as he is well aware, that beauty and simplicity on paper will urge but weak claims to attention, if they are not backed by pretensions to cheapness. Some data are, therefore, added, on which a calculation of the price of light obtained by the means here described, may be founded. One Argand flame, 2 inches high, and $\frac{1}{8}$ths of an inch in diameter, yields a light at least equal to that of four wax candles, (four to the pound); and in maintaining this effect, 1 ounce, by measure, of benzole, per hour, is evaporated and consumed, with the assistance of about 7 cubic feet of air which convey it to the burner. The equivalent of candle light is calculated in the usual manner of equalizing the shadows, and squaring their distances from the lights. The luminiferous liquid may be obtained from the crude naphtha distilled from coal tar. Now this naphtha is worth about one shilling per gallon, and of it the available volatile matter forms from one-fourth to one-sixth of the bulk; and the cost of separation is only that of rectification through an apparatus of simple construction, which may be easily fitted to the stills already in use. The residual liquid, when rectified in the usual manner, is not to be distinguished from the fine coal naphtha of commerce, in many of the purposes to which that product is applied; or if, farther, there be extracted from it, as proposed by the Author, one, or more of the oils, of which it is composed, and which have distinct useful properties, its value will exceed that of the best naphtha at present made. The price of good coal naphtha is raised by the rectification and the materials consumed in its purification, to about 2*s*. 6*d*. per gallon, and always meets with a ready sale. The cost of the still-head, for separating the benzole, will add so trifling a sum to the original expense of the ordinary apparatus, (with the working of which it in no way interferes,) that it may be neglected in the computation; the additional fuel and attention, requisite in the operation, are very small; and the most volatile oils require less purification than the other part of the produce; so that there is no reason why the benzole should bear a higher price than the common naphtha. The price, therefore, of the benzole for gas-light, may be estimated at about 2*s*. 6*d*. per gallon.* Now at one ounce per

* When naphtha bears a higher price than usual, the finest rectified naphtha is sold at 3*s*. 6*d*. per gallon: under these circumstances, it might not be found practicable to sell benzole at a price lower than this; but even at 3*s*. 6*d*. per

hour, a gallon will last about one hundred and twenty hours; thus the cost of the illuminating material, for a light equal to four of the best candles ever used, will be a farthing per hour, or, for an equivalent to one such candle, ·063*d*. To this must be added the interest on the original outlay in pipes, &c., and the expense of maintaining the air current. Of the practical cost of these, the Author must leave the calculation to experienced Engineers.

However, from a rough computation, the Author believes, that these latter items would not exceed 1*s*. 6*d*. for fifteen days, or one hundred and twenty hours, at eight hours of artificial light per diem. This would bring the cost up to 4*s*. for that period. Now if 1,000 cubic feet of gas are distributed over one hundred and twenty hours, not quite 8·4 cubic feet will be consumed per hour. So benzole may be compared with coal gas as an economical source of light, by ascertaining whether 8·4,—say 8½,—cubic feet of gas can give as good light per hour, as the flames of four, (1 lb.,) of wax candles, at a price as low, in any given locality, as 4*s*. per 1,000 cubic feet. If it should prove, that one gallon of the liquid hydrocarbon is equivalent in luminiferous power, to about 1,000 cubic feet of gas, it will be evident, that the oil would be preferable to the gas, in places where the carriage of coal is expensive. For to produce 1,000 cubic feet of gas, at least 200 lbs. of coal are required, whereas one gallon of benzole does not weigh more than 7 lbs; so that the expense of moving the material would be as 1 to 28 in favour of benzole.

The Author does not imagine, that the statements he has here made will at once produce a conviction, that the system proposed is, in all points, perfect; but he hopes they may suggest, to some practical minds, the possibility, that its framework may be, fundamentally, sound. Since he has represented his invention as in some degree, similar to, yet distinct from, three others; it may be interesting here to recapitulate the essential characters of each of these, as marking out the ground left by them for his own to occupy.

First,—Donovan's method of using hydrocarbon liquids to confer luminiferous power on "inflammable gases," not by nature possessing it, by the aid of complicated arrangements for burning them.

Secondly,—Lowe's plan of increasing the lighting-property of "coal gas," by volatile oils, without complex apparatus, or the assistance of heat.

Thirdly,—Beale's scheme for assisting common naphthas to give

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gallon, it would be, at least, as cheap as coal-gas as a source of light, in places distant from the sources of coal.

light, by "atmospheric air" laid on in pipes, with peculiar appliances of heat.

The Author's proposal may be considered as supplemental to each and all of these, and may be described as a method of charging common air, or non-luminiferous gas, with a highly-volatile naphtha, so as to consume it for the purposes of light, without the aid of heat, or of curious lamps for burning it.

The Author cannot conclude, without instancing a confirmation of the law of simultaneous invention, which is in natural connection with the subject, nor without, at the same time, doing homage to the ingenuity of the gentleman whose name he has here again occasion to quote. As the Author was writing the last paragraphs of this communication, a Paper, lately published by Mr. Donovan, was, for the first time, pointed out to him. In it are described some contrivances for burning naphthalized air, which have evidently flowed from a line of thought and of experiment, nearly parallel to that of the Author. Many of the later processes and results seem, indeed, to have been almost identical; but Mr. Donovan appears, for want of benzole, to have stopped just short of a scheme for the general distribution of luminiferous air. The account alluded to was read, February 28th, 1848, before the Royal Irish Academy, and is printed in vol. iv. p. 75, of their 'Proceedings.'

Mr. Lowe said, that in following the train of experiment first taken up by Mr. Faraday, Mr. Mansfield had obtained some highly interesting results; he had introduced to the Meeting the practical uses of a new class of highly-volatile hydrocarbons, and he hoped their introduction would prove as useful practically, as it was, theoretically, simple and good. A somewhat similar idea had occurred to himself; he had a light supplied on the naphthalizing principle, burning in his own house in 1822, before Mr. Donovan had made any experiments in that direction. He had, at first, used small meters charged with naphtha, the fluid being maintained at the same level, by means of a bird-fountain; these trials led to the general use of naphtha, for improving the quality of the flame of the common gas, as he had explained in 1824–25, in his evidence on the London and Westminster Gas Bill, where he fully stated the effect of the process of naphthalizing: and there could be no doubt, that the richness of gas, and those of its qualities which rendered it suitable for illumination, were chiefly derived from naphtha, naph-

thaline, and other hydrocarbons. His patent for naphthalizing coal-gas was taken out in 1832.

He thought Mr. Mansfield was entitled to great praise, not only for the valuable results of his researches, but for the immense labour he had bestowed on the subject; it was understood, that many hundreds of well-recorded experiments had been made by Mr. Mansfield, before this application of these new volatile oils had been matured; one, only, of a considerable series of these substances had been prominently brought forward on this occasion, but it might be expected, that equally practical uses would be found for nearly all the others.

Mr. MANSFIELD apologized for having, in this historical sketch, apparently omitted the facts relative to the period of Mr. Lowe's experiments, which, it appeared, had preceded those by Mr. Donovan. They did not appear in the specifications at the Patent Office, which were the only records to which Mr. Mansfield had access.

In answer to questions, he stated that a gallon of crude benzole would cost about two shillings and sixpence, and that it would be equivalent to 1,000 cubic feet of gas; that conclusion he came to by the quantity of light obtained, as stated in the Paper. The benzole-vapour might possibly crystallize, but not until the pipes were exposed to a very low temperature, below the freezing point, which, practically, was scarcely probable.

Coal gas was a mixture of several hydrocarbons; naphthaline was one of those which crystallized at the ordinary temperature of the air, and it was that substance which did crystallize in the gas-pipes; not a trace of that substance was to be found in the benzole. The crystallization could not be said to arise from any excess of carbon in the composition, but from a physical property of the substance, of which, as yet, nothing was known, except that it was so; other substances containing an equal amount of carbon did not exhibit that tendency.

Mr. LOWE said, it had been often urged against naphthalizing coal gas, that the naphtha would be deposited in its transit through the pipes: to set the matter at rest, he naphthalized all the gas in a gasometer at the Brick-lane Station, and conducted it for a distance of one mile, into another gasometer at the Curtain-road Station, without there being any perceptible difference; it had not lost any of its luminiferous properties, in passing from one station to the other. If its temperature was greatly reduced by passing through a colder medium, after having been naphthalized at a temperature of 70°, or 80°, a portion of it would be deposited; but from that, the gas, or air, should be well saturated at that high temperature. Now it was never requisite to saturate coal gas, when it was wished

to double its illuminating power, in fact, it only received, practically, one-fifth part of saturation; it was found, that if 1,000 cubic feet of coal gas took up one gallon of naphtha, it obtained considerably more than double its former illuminating power. It had been tried for a time at the engineering department of the South Western Railway, with and without the naphtha, and the result had been, that with the naphtha the gas gave a superior light at, he believed, not more than half the ordinary cost. Mr. Lowe had never found any deposit of naphtha in the pipes, or fittings. Such a deposit had been stated to have occurred in the House of Commons, but the fluid found in the pipes arose from the water-meter placed in the heated roof, where the water was soon evaporated by the heat, and was condensed in the first favourable spot. He doubted whether the naphtha could be obtained at one shilling per gallon; that which he used cost two shillings and sixpence per gallon, and it was a question how much benzole could be obtained from that quantity. The best naphtha now in use, was procured from Dundee, and was made from cannel coal.

Mr. MANSFIELD replied, that the crude naphtha from which he made benzole, had only cost one shilling per gallon, when purchased in small quantities; in the Paper, he had quoted two shillings and sixpence per gallon for the rectified naphtha, which was that to which Mr. Lowe referred.

In answer to a question from Mr. Lowe, Mr. Mansfield stated he had procured a proportion of one-fourth from the best crude naphtha, which was that from Scotland and the north of England; he thought the London naphtha would not yield more than one-sixth; there would, after the extraction of the benzole, be still the sale of the residuum product, which he thought would bear nearly the same price as before, those of its properties from which its value for many purposes arose, not being appreciably diminished, and some of them being actually enhanced by the abstraction of the benzole.

Mr. LOWE thought there would be little advantage to the coal gas, in using naphtha from which the benzole had been extracted; that had formerly been the impediment to the first invention. The naphtha sold in London was of so bad a quality, that little more than one-third could be volatilized, and it was so loaded with sulphurous compounds, that the gas, after being naphthalized, could not be burned in sitting-rooms.

Mr. MANSFIELD explained, that the uses of naphtha, to which he alluded, were not those in connection with illuminating gas, but various others, which occurred in the arts; he believed, however, that one of the oils, constituting the residual naphtha, of which there

was fully as much as there was of benzole, in the crude material, would answer quite as well as the finest naphtha of commerce, for the purpose of improving the illuminating power of gas.

Mr. RETTIE said, the value of this, as of every other invention, must be tested by its utility, safety, cheapness, and cleanliness. It was important to ascertain, whether the proposed light could be used in the same simple way as the lights in present use, without fear of accident. He admitted, that the light exhibited was beautiful, but, he submitted, that unless it was free from the objections to camphine and all spirit-lamps, there was little chance of its coming into general use. Camphine, if it had been less dangerous, would have been more generally used, notwithstanding the annoyance of its producing, at times, such volumes of smoke and soot. The new system had much to contend with, and would have still more, if the quality of the London gas, and the workmanship of the fittings and burners was improved; he also thought the gain in point of economy was not clearly demonstrated.

Mr. WYNDHAM HARDING begged, in the absence of Mr. Gooch, to confirm what had been stated, with respect to the experiments at the South Western Railway, the general results of which were, that by the use of naphthalized gas, there was a clear saving of 30 per cent. The plan had been tried for two, or three months, on a small scale, and not any disadvantages had been discovered; it was, therefore, intended to try it on a larger scale.

Dr. HOFMANN stated, that the very accurate and lucid descriptions which Mr. Mansfield had given of his system of illumination, precluded the possibility of his offering any remarks which could be of value, or interest to the Meeting. He had had the pleasure of witnessing the progress of Mr. Mansfield's experiments upon coal-tar, and was highly gratified with the results which his perseverance had obtained. As to the brilliancy of the light afforded by the apparatus, which had been exhibited, there could be no doubt; and as to the danger, apprehended by the gentleman who had just spoken, he could not see it; he thought that this method would not present any more danger than the use of ordinary gas. The question of economy he would leave untouched, but he was confident, that Mr. Mansfield had made his calculations with great care and circumspection. He hoped, that an opportunity would soon be offered to Mr. Mansfield, of removing, by experiments on a sufficiently large scale, any doubts which might be still entertained, respecting the practical value of his invention. He could only add, that the scientific combination of chemical principles by which Mr. Mansfield had perfected his contrivance, was exquisitely beautiful.

Mr. WHISHAW said, he had used camphine-lamps since they were first invented: with moderate care there could be no danger, and certainly, the lamps gave the most beautiful light that could be introduced into a house. With regard to economy, his three camphine lights cost him fourpence a night.

Mr. R. STEPHENSON, M.P., *V.P.*, said, he thought there was no chance of danger in the proposed system, as the pipes were intended to convey the common air, or other gas from the air-holder through a metallic vessel containing the benzole, which would be placed in the cellar, or in an outbuilding.

He mentioned the gazogène-lamps now commonly used in Paris, which were simply composed of a vase containing, he believed, alcohol and oil of turpentine, the spirit of which ignited without any wick, at the upper extremity of a tube, which plunged into the liquid. This system of illumination was simple, and the light was pure and white; but in England it would be too expensive, in consequence of the cost of the alcohol.

Mr. APSLEY PELLATT thought if Mr. Mansfield could manufacture the benzole from the mere residue, there would be a probability of his making a cheaper article than if it were produced directly from the raw coal, although as a general rule, it was the proper system to manufacture from the raw material. With respect to the London gas, most of the Companies were in active competition with each other, as to which of them should introduce the purest article, and Mr. Lowe could corroborate the assertion, that the London gas was as much as possible cleared of sulphur, and nearly of ammonia. There was, however, one great mistake, which he thought all gas manufacturers fell into, looking more to the cost of the material than to the expense of conveying it; there was still too great leakage from the pipes, and then there were heavy expenses of inspection and of general establishment, and many bad debts, all of which diminished the dividend of the proprietors, and caused the high price of gas when sold, as compared with its actual prime cost. Great pains were taken, not only to render the gas pure, but to give it all the carboniferous matter it ought to possess, and constant improvements were introduced, with a view not only to the amelioration of its quality, but also to the processes of manufacture. Exhausters had been recently used for the purpose of taking the pressure from the retorts, and facilitating the subsequent stages of purification: this recent introduction was expected to be of considerable importance in the manufacture.

April 24, 1849.

WILLIAM CUBITT, Vice-President, in the Chair.

No. 794.—"On the Construction of Locomotive Engines, especially with respect to those modifications which enable additional power to be gained, without materially increasing the weight, or unduly elevating the centre of gravity."* By Thomas Russell Crampton, Assoc. Inst. C.E.

A FEW remarks on the construction of locomotive engines, with respect, more particularly, to the means of gaining additional power without materially increasing the weight, or unduly elevating the centre of gravity, may prove interesting at the present time, when the attention of Engineers is drawn to the subject of the steadiness of locomotive engines moving at high velocities, upon which depend the durability of the working parts of the engine, the stability of the permanent way, and that freedom from oscillation which is so much appreciated by travellers. Owing to the extraordinary increase in the traffic on some of the principal lines of railway, it has been found necessary to employ engines of much greater power, and consequently, of a much heavier and more bulky description than those previously used: this, in conjunction with the use of large driving-wheels, has rendered engines of the ordinary construction upon the narrow gauge, so lofty and objectionable, as to suggest the propriety of some plan being generally adopted to obviate the evil. It can be shown, that for narrow-gauge lines, by means of several important modifications of the arrangement of its component parts, a steady engine can be constructed, affording a much larger extent of heating surface than has been hitherto allowed, whilst the height may be quite independent of the diameter of the driving-wheels.

Before describing an engine possessing these qualities, it may be well to point out the principles adopted in the construction, for insuring the greatest amount of steadiness. In order to divest the subject of extraneous considerations, it is assumed, that an engine supported upon four wheels of a given diameter whose axles are at its extremities, having the line of traction identical with the centre of gravity of the moving mass, (as shown in Fig. 1, Plate 7,) may be lowered to, and rendered identical with, the horizontal and vertical centres of the buffers and draw-bars. By such an arrangement, it

* The discussion upon this Paper extended over portions of three evenings, but an abstract of the whole is given consecutively.

would have the least possible tendency to oscillate, and any rocking, or vibrating motion would solely depend upon, and follow, the irregularities of the rails on which it travelled. If this is granted, it follows, that to insure steadiness, the nearer this principle can be approached, by confining the weight between and on the extreme limits of support, the less will be the tendency to jumping and to lateral motion; and this view may be rendered still more forcible, by assuming the weight to be placed on only one pair of wheels of the same given diameter, the weight of the mass on either side being balanced as shown in Fig. 2. It will be evident, that in this arrangement, there would be considerable tendency to oscillate, from any disturbing cause, and this tendency would, moreover, be increased by the line of draught being considerably below the centre of gravity of the moving mass.

Upon the supposition, that safety and economy are dependent on freedom from oscillation, it is desirable to ascertain, to what extent the principles just alluded to, have been observed in the construction of ordinary engines. Fig. 3 represents the general outline of an outside-cylinder engine, whose axles are all confined within the fire and smoke-boxes. The driving wheels being in the centre, may here be regarded as a fulcrum, in consequence of the greatest weight being placed on the driving-axles; any inequality, therefore, in the road, would cause the weight to be thrown alternately upon the fore and hind axles. This oscillation, once induced, would augment with the increase of speed, and taken in connection with the high centre of gravity and the overhanging weight fore and aft, would appear to produce the rocking and rolling motion in this class of engines, independent of any tendency to vibration, arising from the working of the unbalanced parts of the machine.

Fig. 4 represents an improved outside-cylinder engine, in which the three axles are, also, within the fire and smoke-boxes, and the cylinders are placed between the small wheels; thus avoiding the overhanging weight of the cylinders and of part of the smoke-box. In this engine, the tendency to rock is greatly reduced, by the position of the driving-wheels, the centre wheels having to bear less weight, than in the former case, and the cylinders being placed behind the leading-axle. The unsteadiness of this machine would, therefore, appear to arise from the weight of the overhanging fire-box which, in large engines, is considerable, and from the height of the centre of gravity above the rails.

Fig. 5 represents an ordinary outside-cylinder engine, in which the driving-axle is placed under the body of the boiler, the trailing-wheels behind the fire-box, and the cylinders and smoke-box project-

ing considerably beyond the leading-axles. The unsteadiness of this class of engine would appear to arise from the driving-wheels being placed in the centre, and thus having to support the greatest weight, and also from the effect of the weight of the overhanging smoke-box, which is aggravated by the position of the cylinders, as well as by the high centre of gravity.

Fig. 6 is an ordinary six-wheeled inside-cylinder engine, the distribution of whose weight corresponds nearly with that of Fig. 5, except in the reduction of the overhanging weight in the front; the cylinders being placed close to the leading-axle. This engine has also the disadvantage of the greatest weight being placed in the centre, on the driving-wheels, and of having an increased height of about nine inches, in consequence of the cranks and eccentrics being placed beneath the body of the boiler.

Fig. 7 is an ordinary four-wheeled inside-cylinder engine: in this case, the smoke and fire-boxes extending beyond the leading and driving-axles, the overhanging weight is considerable, in proportion to the distance between the supports, and this, together with the high centre of gravity, appears to be the cause of its unsteadiness.

The advocates of inside-cylinder engines contend, that the unsteadiness of outside-cylinder engines arises from the great distance between the cylinders, and from the momentum of the moving parts, on each side, not being equally counterbalanced, and consequently, that this tendency must be greatly neutralized, by bringing the cylinders as close together as possible. In order to support this opinion the inside-cylinder engine, (Fig. 6,) is frequently compared with the outside-cylinder engine, (Fig. 5); it will be seen, however, that the overhanging weight in Fig. 5, tends considerably to augment the vibrating action, whereas in Fig. 6, where the cylinders are close to the leading-axle, this cause is diminished, the less amount of vibration in Fig. 6 not entirely arising from the extra leverage of the momentum. To show the importance of the position of the cylinders longitudinally, it is only necessary to refer to the fact, of a preference being given to the engine, shown in Fig. 4, over that of Fig. 3, in the former of which the motion of all the working parts is brought within the front axle, whilst the axle of the driving-wheel is placed behind the other two, bringing the greatest weight upon the hind axle. The variation, shown in Fig 4, has proved eminently serviceable to this class of engine, and is calculated to render it better adapted to high speeds.

In attempting to compare the peculiarities of each class of engine, it is of importance to bear in mind the relative weights placed upon each axle, and at the same time, to assume, that each engine has the

same power. The weights marked in tons upon the driving and other axles in the diagrams, will be found sufficiently near for the purpose of explanation, the average weight of each engine being assumed to be twenty tons, ten tons being placed on the driving-axle, and the remaining weight being distributed over the other two; the driving-wheels, in all cases, being 7 feet in diameter.

It is contended, in favour of outside cylinders, that the absence of cranked axles, the reduction in the height, the increased facilities for inspection and repairs, as well as the greater simplicity of the working gear, render these engines preferable, in every respect, to those of the inside-cylinder class, in which the cranked axles, and the length of time required for their adjustment and renewal, the height, the inconvenience of inspection, and the difficulty and expense of repairs, render a larger stock of engines necessary to perform the same amount of work.

This cursory examination of the construction of the engines, which are now ordinarily used, shows that they rather appear to possess those qualities exhibited in Fig. 2, instead of confining the weight between the extreme points of support, without any overhanging weight, as shown in Fig. 1; it is, therefore, necessary to describe an engine which would appear to embody those essential points, without rendering it necessary to deviate from the acknowledged proportions, which are found to produce the most useful effect, whether it be in the construction of the boiler, or the arrangement of the details.

Fig. 8 represents the general outline of an engine, in which the boiler is brought as low as is practicable, the driving-axle is placed behind the fire-box, the two smaller wheels under the body of the boiler, and the cylinders between the smaller wheels, as in Fig. 4. It will be seen, that nearly the whole weight is thus placed on and between the extreme points of support, which have, consequently, the greatest weight directly upon them, very little being thrown upon the centre wheels. Any inequalities of the road, therefore, operate, with this engine, in a contrary manner to the others, and the line of draught of the moving mass, or the centre of the draw-bars, being very nearly in a line with the centre of gravity, accords with the principles alluded to in Fig. 1. The boiler is of the ordinary form, having about 1,150 feet of heating surface, with driving-wheels 7 feet in diameter; the cylinders, which are each 16 inches in diameter with 20 inches length of stroke, are fixed between the centre and the leading-wheels; the motion is communicated to the outside cranks by means of connecting rods of the usual kind, and the slide valves are worked by eccentrics, placed outside on small return cranks.

The framing consists of four longitudinal plates, arranged in pairs, 18 inches apart, on each side of the boiler, of which it is entirely independent; the centre, both vertically and horizontally, corresponding nearly with the line of draught, or centres of the buffers and draw-bars, and very nearly with the centre of gravity of the engine. These frames are firmly secured together, by means of transverse plates, one at the front, to which the buffer-board is attached, two at the part where the cylinders are placed, one immediately in front of the fire-box, two forming the guides for the reception of the axle-boxes of the driving-wheels, secured only to the inside framing and one at the end of the foot-board. The leading and the centre axles have outside bearings, and the axles of the driving-wheels have inside bearings; the whole of these bearings are much longer than usual, those for the driving-wheels being 12 inches in length, and the centre and front axles being 10 inches in length, whilst in the ordinary engines the bearings for the driving-wheels, in consequence of their position, are usually not more than 6 inches long. The regulator is attached to the outside of the boiler, and has a direct communication with the cylinders, by which arrangement any adjustment, or repairs can be made with the greatest facility.

The advantages which are believed to result from the adoption of this form of engine, are economy in the maintenance of the permanent way, owing to its steadiness when moving at high speeds,—facility for the repair of the working parts of the machinery, in consequence of the whole of it being outside,—and non-liability to the accidents arising from the machinery being placed underneath; there is also less liability to derangement, owing to the position of the machinery bringing it constantly within the view of the driver, and so great is the facility for examination, that even all the bearings can be oiled when moving at any velocity. The repairs requiring less time than with other engines, a smaller number of spare engines would be necessary, provided the workmanship were equal, and the general facilities for cleaning and examining the working parts of the machinery, without creeping underneath the engine, tend greatly to reduce the amount of incidental expenses, which ordinarily form an important item in railway expenditure.

The evident advantages which result from the employment of large driving-wheels, in the economy and in the maintenance of the working parts of the engine, owing to the whole being reduced in speed, by the fewer number of revolutions with the same velocity along the line, have not, till lately, been fully appreciated. Some of the first experiments made with driving-wheels of large diameter, disappointed the expectations of the Engineers: this, however, arose

from the disproportion which existed between these wheels and the amount of heating surface and content of the cylinders, but it is now found, that one pair of wheels, 8 feet in diameter, has sufficient adhesion to draw a load of 180 tons at a speed of fifty miles per hour. Although the early experiments proved unsatisfactory, yet, at the present time, the greatest performances are accomplished with driving-wheels 8 feet in diameter, and within the last seven years, no wheels of less size than 7 feet in diameter have been employed on the Great Western Railway.

The means by which a much larger amount of power may be introduced, with any required diameter of driving-wheels, will be readily understood, by reference to Fig. 8, where it will be seen, that the lower portion of the cylindrical part, or body, of the boiler may be brought down to the axles of the smaller wheels, instead of being dependent upon the diameter of the driving-wheels, as in the engines, Figs. 3, 4, 5, 6, and 7. By making the boiler of an oval form, a very large amount of heating surface may be introduced, without increasing the height beyond the ordinary standard; it will be seen, moreover, that the barrel of the boiler may, if desirable, be made to project over the small wheels, and the fire-box may be increased in width, at the part where it unites with the barrel, in front of the driving-wheels, as in Fig. 11.

Thus a boiler, 4 feet 6 inches in diameter, or 4 feet 6 inches wide, by 5 feet 6 inches high, can be constructed, which is not practicable with engines having the axle of the driving-wheel under the body of the boiler. Messrs. Bury, Curtis, and Kennedy have constructed, for the London and North Western Railway, an engine on this principle, in which the cylinders are 18 inches in diameter, with a stroke of 2 feet in length, having driving-wheels 8 feet in diameter, the boiler containing three hundred tubes $2\frac{1}{16}$ inches in diameter, and 12 feet 3 inches in length: the total length between the centres of the extreme wheels is 18 feet; the heating surface of the tubes and the fire-box is equal to 2,100 feet, being rather more power than the largest engines on the Great Western Railway, with a greater angle of stability.

Figs. 9, 10, 11, and 12, show the construction of the 'Liverpool,' the large narrow-gauge engine just alluded to; and Fig. 13 shows the end of the 'Iron Duke' on the Great Western Railway: the relative angles of stability of all the engines are shown by the lines drawn from the supposed centre of gravity to the rails, as seen on the several end views. The idea of engines having the same sectional area of boiler as the 'Liverpool,' could not be practically entertained for the narrow gauge, if the axle of

the driving-wheels were placed under the body of the boiler, as in Fig. 14.

Though the distance between the unbalanced moving parts is somewhat increased, laterally, in this engine, in comparison with the inside-cylinder engines, yet it will be seen, that the absence of any fulcrum, upon which these foci can act, reduces the tendency to vibration, which exists in other engines. Some evidence of the absence of oscillation may be mentioned, in reference to one of the first engines constructed upon this plan, in which the bearings of the leading and trailing wheels were not worn more than one sixty-fourth part of an inch sideways, after having run a distance of nearly thirty thousand miles. It may be observed, that this arrangement is equally applicable to the construction of small tank engines. The whole of the machinery being placed outside, allows the space, underneath the body of the boiler, to be occupied by a water tank: the boiler being low, plates about 4 feet high are fixed round the fire-box and the foot-plate, to protect the driver from the weather, thus forming a convenient receptacle for the coke, on the top and sides of the fire-box, the weight of the engine, water, and fuel being therefore between the extreme points of support. It is believed, that this description of tank engine is superior to those in use, on account of the distribution of the weight, as well as for the facility for inspection and repairs. In confirmation of the truth of the principles, here advocated, it may be stated, that the plan of reducing the weight on the centre wheels, in six-wheel carriages, by having lighter springs than those fore and aft, is now universally adopted on the London and North Western Railway: the oscillation is thus greatly reduced, by avoiding that scale-beam action on the centre wheels arising from the inequalities of the road. It is possible, that a portion of a line of railway might, for experimental purposes, be put in such perfect order, that the relative weights upon the wheels would not be of so much importance; but since such a state of things is incompatible with the general working, it would appear, that too much attention cannot be paid to the arrangement of the weights on the wheels, in order that they may be disturbed as little as possible, both laterally and vertically, by the inequalities of the road.

Having now offered a few observations upon the engine commonly used, and described the engine, in which additional power is gained, without materially increasing the weight, or unduly elevating the centre of gravity, it may, perhaps, be necessary to observe, that it is not professed that the latter consumes less fuel than other engines, in proportion to the work performed: the main advantages consist in its capability of running at high velocities without oscillation, in

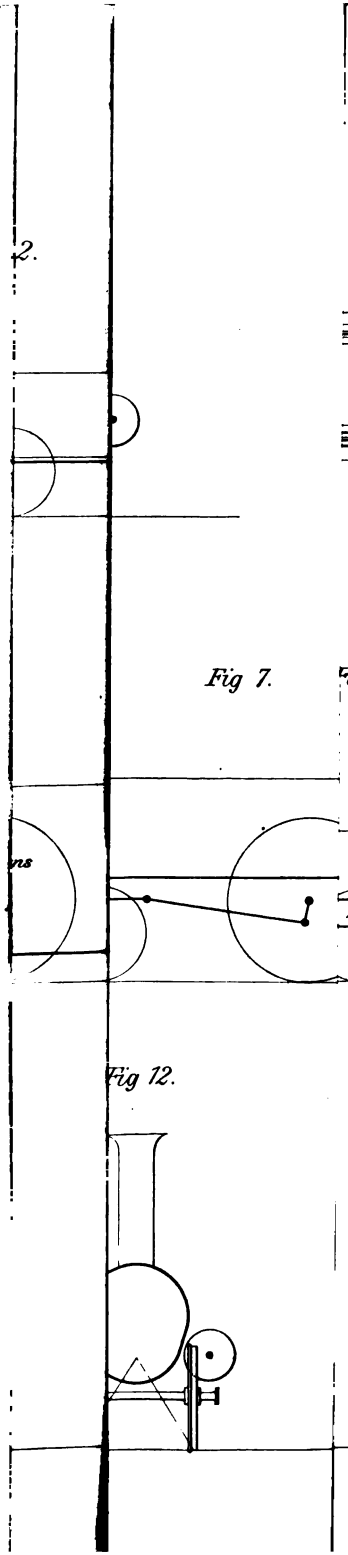
not interfering in any degree with the adaptation of known, or favourite proportions of the detail of the machinery, the fire-box, or of any other part, which might influence the performance of the engine, and in not rendering necessary any increase in the height of the engine, whatever may be the diameter of the driving-wheels; thus insuring a greater durability of the working parts of the engine, and of the flanches of the wheels, as well as a saving in the repairs of the permanent way. It must always be borne in mind, that the description of workmanship is most important, and that no comparisons can be correctly drawn, unless this point be attended to.

The opinions relative to obtaining the greatest amount of steadiness, and the consequent durability of the locomotive engine and of the permanent way, by placing the greatest weight between and on the extreme points of support, are advanced for the purpose of eliciting the opinion of practical men, on these points of vital importance in the construction of locomotive engines and in the working of railways, and if, in the discussion, they are proved to be incorrect, that they may, at least, have the merit of having induced the Members of the Institution of Civil Engineers to lay down the true principles, which should be kept in view for these purposes, by which a lasting boon would be conferred upon the railway interest and the public.

The Paper is illustrated by one drawing, (No. 4,391,) and a series of diagrams, from which Plate 7, (Figs. 1 to 14,) is compiled.

Mr. CRAMPTON said, with respect to coupled engines, that in a goods engine, now on the Edinburgh and Northern Railway, the wheels were placed at each end, in such positions, that they all had to sustain equal weights. The centre, or crank axle being fixed in the frame, enabled the moving machinery to be fixed on springs and to work like stationary engines, uninfluenced by the inequalities of the road, and by the arrangement, the angular thrust of the connecting rods was neutralized and did not affect the road. When the wheels were coupled, they should be made to sustain equal weights, because equal power was transmitted through them. In the case of an ordinary six-wheeled engine, with four of the wheels coupled, the weight being equally apportioned between the three pairs of wheels, the inequalities of the road would have the effect of varying the proportions of the load, to such an extent, as to throw, at times, an undue amount on one pair; and since a constant power was transmitted through the coupling rods, unless the wheels were in

PLATE 7.



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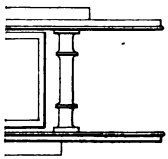


Fig 7.

Fig 8.

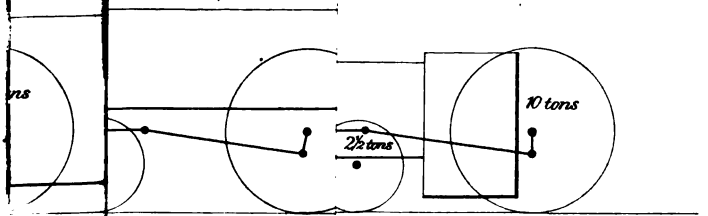
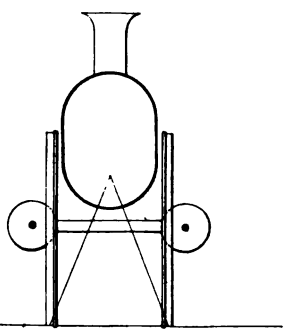


Fig 12.

Fig 14.



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a condition to employ that power advantageously, the effect was to impart undue vibration to the machine. The engine on this principle, to which he had before alluded, travelled with a remarkable degree of smoothness on an undulating line.

Mr. R. STEPHENSON, M.P., *V.P.*, said, that Mr. Crampton appeared to attach more importance, than any other locomotive Engineer, to placing the wheels at the extremity of the engine, and though, as between competitors in design and construction, a difference of opinion, on certain points, might appear to exist, Mr. Crampton had been such an industrious labourer in the field, that any observations made by him were entitled to great weight. The distinguishing feature, between the two systems, was in the arrangement of the wheels under the engine. Steadiness of motion might be obtained, by augmenting the area covered, or in other words, by extending the distance between the extreme wheels, on the rails, and when once that point was attained, it was nearly a matter of indifference where the propelling power was applied. By the mode of placing the driving-wheels behind the fire-box, steadiness was, doubtless, obtained, but he contended, that it was procured at the price of other inconveniences. The main difference, between this system and that of all other Engineers, in the arrangement of their engines, was in the mode of covering a sufficient area on the rails; the usual method being to apply the power upon an axle placed somewhere intermediate, with respect to the extreme bearing-wheels; whilst Mr. Crampton insisted, that the action should be direct upon an axle, situated at, or near the extremity. The engine, shown in Fig. 3, was first designed for the purpose of obtaining an economical consumption of fuel, which, at that time, was considered of paramount importance; it had been termed the long-boiler engine, and though, at the period of its introduction, it had been considered a decided step in advance, it had since been stigmatized as combining all the faults that could be comprised in any engine. When it was first introduced, the size of turn-tables was such as to offer an inducement to keep the wheels as close together as possible. The rivalry between railways had been so great, within the last few years, that every effort had been made to obtain power and speed; consequently, the distance between the wheels had been extended, and the extension had induced a greater degree of steadiness, on account of the greater area of railway, covered by the engine.

He thought the railway authorities were nearly equally divided, on the question of outside, or inside cylinders. At one time, it was deemed advantageous to have the working gear outside, that it might be readily cleaned and be under the eye of the engine-driver;

and certainly, at first, that appeared to be a specious argument, but it was not a sound one. He had been one of the first innovators, in using outside cylinders, but after years of experience, he was inclined to regret the change. It would be remembered, that outside cylinders were originally employed on the Liverpool and Manchester Railway, but the oscillation was there found to be so great, that the system was changed, and the power was applied inside the framing. The breaking of cranked axles was so serious an objection, for engines on foreign railways, that outside cylinders were adopted for the purpose of dispensing with them, particularly as high speeds were not required; the straight axles being more economical and more easily repaired. It was still very difficult, on the Continent, to make a good crank, therefore it was desirable to remove that impediment; but as the same objection did not exist in England, he could not coincide with the adoption of a system which, in any degree, tended to induce unsteadiness, particularly considering the present high rate of travelling on English railways. It was true, that the engine-driver could see the outside cylinders, when travelling, but he thought that was not important, when an engine was going at the rate of thirty miles, or forty miles per hour; and when the engine was in the shop, it was of little importance whether a man crept underneath, or got up outside, to clean, or to repair it. Whether the wheels were placed precisely as Mr. Crampton had arranged them, or as in other classes of engines, at an intermediate point, was, he thought, almost a matter of indifference; he alluded more particularly to those engines with eight wheels, like the 'Iron Duke;'—and for great power and high speeds, he believed that arrangement to be the best. Inside bearings and inside cylinders were scarcely compatible, as the cylinders occupied so much space; but an increase in the length of the bearings, as arranged in Mr. Crampton's engines, was a decided improvement. The whole question turned on a balance of difficulties: every form, into which a machine could be thrown, might possess distinct advantages and corresponding disadvantages, and for that reason he was glad the Paper had been brought forward, since it would afford all parties an opportunity of expressing their views, and would enable them to avoid the too common error of adopting a particular idea and of applying it indiscriminately to all cases.

Mr. BRUNEL directed attention to the fact, that the wants of the public were continually varying, and consequently, the peculiarities of the machines must be varied to meet them. When Mr. Stephenson's long-boiler engine was designed, economy of fuel was the main consideration, and that machine was the best adapted to attain

the object. Shortly afterwards, high speeds were aimed at, and that rendered other alterations necessary in the construction of the engines. Thus a form which was the best to-day might be the most defective to-morrow; not because the machines were bad, but because they could not meet the requirements of the time. There might be advantages and peculiarities in the construction of Mr. Crampton's engine which would eventually produce good results, but he could not believe they were attained by the driving-wheels being placed behind the fire-box; that must be a defect which, however, might be counterbalanced by some advantages. He agreed with Mr. Stephenson in thinking, that the eight-wheeled engines, with the driving-wheels near the centre, promised the greatest degree of steadiness, and the best general distribution of the weight on the rails; and he thought experience tended to show, that it was the area of the base, rather then the position of the wheels, which produced steadiness. Originally, he entertained the idea, that when the weight was placed outside the base, it might induce a want of steadiness, but from experiment, he was now disposed to think, that the effect was less than was generally supposed, and that the extent of the base, as compared with the height of the centre of gravity, was that alone which affected the steadiness. He did not think the arc, through which the body moved, when it was pitching longitudinally, was sufficient to influence the steadiness of the engine; and therefore, he must contend, that the position of the driving-wheel, within certain limits, was not of much importance. With respect to throwing a considerable part of the weight on the centre wheels, unless, in order to prevent them slipping, they were screwed up so tight, that the engine was virtually running only on two wheels,—which was unsafe,—in ordinary cases he did not think the system led to any disadvantage. Mr. Brunel had always been an advocate for six-wheeled carriages, and he had fancied it was desirable to make the centre spring lighter than the end ones; desirous, however, of carrying out the experiment to the extreme, he took off the centre wheels from a loaded six-wheeled carriage with long bearings, the body extending beyond the extreme wheels, and ran it on four wheels, but he could not discover the slightest difference in the motion. He had, therefore, come to the conclusion, that within proper limits, no unsteadiness was produced by having the greater weight thrown on the centre wheel. His present feeling was in favour of engines with the driving-wheels near the centre, and with inside cylinders, and he concurred with Mr. Stephenson in thinking, that outside bearings were, all things considered, the strongest and safest, not interfering with, or cramping the machinery within.

Mr. J. V. Gooch said, he had carefully considered all the points urged by Mr. Crampton, in the arrangement of his engine and the various other engines shown in the diagrams. The great object was the economical and effective application of power to attain speed, by the means at the disposal of railway companies, and one of the regulating circumstances to be kept in view, was the present construction of the permanent way, which not only limited the weight of the engine, but also the speed. During all the experiments which had been made by various parties during the last few years, he had continued to use, what were considered small engines: the driving-wheels were 6 feet 6 inches in diameter, there were four bearing-wheels, the boilers were 10 feet long, and the cylinders 14½ inches in diameter, with a length of stroke of 21 inches; yet he believed he obtained as good results, both as regarded speed and economy of fuel, as others had done with larger engines.

He thought, that the arrangement of the weight on the wheels, was more to be attended to, than whether the driving-wheel was in the centre, or at the extremity; he, however, preferred it near the centre. One of the evils of the present large engines was, that in attempting to obtain great power, by large cylinders and a very long stroke, an unnecessary weight was imposed on the driving-wheels, thereby causing the engines to be unsteady. He found it was preferable to run the trains with a light weight on the driving-wheels, rather losing a little time in starting from the stations, than running with a heavy weight upon those wheels, as the drivers, when accustomed to do so, considered, that an engine would thus run lighter and consume less fuel. He preferred outside cylinders, which he had used for the last four years, and he thought, that the great speeds now attempted could only be obtained by large driving-wheels.

The question was entirely one of a balance of advantages, and his opinion was, that for the present requirements of the narrow-gauge lines, six-wheeled engines with the driving-wheels in, or near the centre, care being taken not to place too much weight on them, were best calculated to do the work at the highest speed, and with the greatest economy.

Mr. Rennie thought it was entirely a mechanical question, as to whether the weight of the engine was properly apportioned among all the wheels, and whether placing these wheels behind was as safe and secure as placing them in the middle. He could, however, apprehend, that danger might be urged, from the twisting motion, which the driving-wheels might impart to the engine, when they were placed at the end, and also, that shocks from a lifting

motion might be feared; but the lowering of the centre of gravity, as represented by the diagram, was of great importance, and almost rendered that class of narrow-gauge engine equivalent to the wide-gauge engines. Mr. Stephenson had brought his engines to such perfection in construction, that all questions appeared to be now mere matters of detail in arrangements, which revealed themselves in the results of actual working.

Mr. ADAMS said, he had lately, in conjunction with Mr. Samuel, constructed some small engines, in which the chief object was to reduce the total amount of dead weight and friction. He had entertained the notion, that for certain purposes, by having the engine and carriage upon one frame, so as to form one machine, he might obtain greater steadiness, than by an engine drawing detached carriages. The experiments, as far as they had yet proceeded, had been satisfactory.

Mr. CRAMPTON said, that he had endeavoured to give reasons for the engine being steadier, when the weight was on the extreme wheels, than in any other position; but the actual position of the driving-wheels was of little importance; and he thought it would be a great point, if the Institution would declare what was the right principle. He admitted, that the engines to which Mr. Stephenson had referred, were much steadier than many others; but he contended, that it was owing to the centre of gravity of the mass of the boiler being further forward from the driving-wheels, than it was previously. The change of the weight, from the centre to the hind part of the engine, had rendered the front of it practically steady: this appeared to arise from the fulcrum action being removed from the centre of the engine, by throwing the weight of 10 tons on the hind wheels, instead of on the middle wheels. Experience had shown, that there was a certain amount of momentum produced by the overhanging fire-box, which had the effect of hammering the rails: to remedy this, a pair of small wheels was added behind the fire-box, as in the 'Iron Duke' engine. He did not dispute the correctness of the position, that the extension of the base gave corresponding steadiness to the engine: this had been demonstrated by the addition of the pair of wheels, as he had just described, when the length was increased from 13 feet to 18 feet 6 inches; but he contended, it did not follow, that a length of 18 feet 6 inches was indispensable for steadiness, when the weight was borne on each end of the machine, although it might be essential, when the greatest weight was thrown on an intermediate point, between the extreme supports. An engine on Mr. Crampton's system, with the centres of the extreme axles 12 feet apart, had

1,200 feet of heating surface, which was more than was generally required, and yet there was no vibration; its construction permitting, at the same time, the adaptation of inside cylinders, if that was considered necessary.

A small engine had been constructed by Mr. Samuel and Mr. Adams, with the wheels 8 feet apart, which, although only weighing about one ton, was perfectly steady, when travelling at the rate of thirty-five, or forty miles an hour: the steadiness appeared to arise from the centre of gravity being kept low, and the weight being thrown on each end of the engine. This, he contended, was an additional argument, that great length was not essential for steadiness, and it was admitted to be very objectionable, when running round curves, besides requiring larger turn-tables.

Mr. Gooch's statement confirmed the principle, that Mr. Crampton desired to establish; namely, that taking the weight from the centre of the engine, and lowering the centre of gravity, even only a few inches, added to its steadiness: how much more, therefore, might be gained by lowering the engine 18 inches, as had been done in several of Mr. Crampton's engines? He thought, that if the Institution would give the younger members of the profession the true principle to act upon, it would confer a boon both on them and the public.

In answer to a remark from Mr. Rennie, Mr. Crampton stated, that an engine only 13 feet long between the bearings and weighing 20½ tons, had run nearly twenty-five thousand miles, without wearing the front brasses more than the thickness of a finger nail. An engine on the South-Eastern line, which had also been altered by removing the driving-wheels from the centre to the end, had been travelling regularly for nine months, without any appreciable lateral wear of the brasses.

It must be observed, that in the ordinary outside-cylinder engines, all the gearing was under the boiler, as in the case of the inside cylinders, and he must direct particular attention to this, because he believed the engines on his system were the only ones, in which the whole of the machinery could be inspected and repaired from the outside.

Mr. R. Stephenson, M.P., *V.P.*, could not agree with the inference, that because the driving-wheels had in one case been removed from the centre to the end, this change had sufficed to render the engine steady; it might have become steady, but he contended, that it was rather in consequence of the alterations having extended the base on the rail, and not from the disposition of the weight on the wheels. He maintained, that the driving-wheels should, in all

cases, be placed at some intermediate point; and he thought, that when they were placed at the extremity, they would be most likely to induce unsteadiness in the engine. He could not understand how it could be maintained, that the power being thrown on the wheels, at the end of an engine, should contribute to render the motion steady; because, in his opinion, the act of communicating power, and the means of attaining steadiness, were essentially distinct questions. The engine, with the driving-wheel in the middle and the two smaller wheels placed to carry the weight of the extremity would, he believed, give the greatest amount of steadiness; and he must repeat, that he thought the end of the engine was the worst position for the driving-wheels; inasmuch as when they were in that part, the connecting rod, through which all the force was conveyed to the wheel, had to bear violent action and reaction at the top and bottom centres, which was repeated two, or three hundred times in a minute, and must, he thought, tend more to produce oscillation, than if the driving-wheels were placed under the centre of gravity. He agreed with Mr. Brunel, that as circumstances changed, it was necessary to change the mode of meeting them, and hence arose the different plans, which, in the end, he thought would lead to the furtherance of their common object, the attainment of perfection in this branch of mechanism.

Mr. CRAMPTON replied, that the angular thrust of the connecting rod upon the driving-wheels at the extremity, was, he contended, in favour of his system. By referring to the diagram, it would be seen, that a certain force was transmitted to the rails, through the connecting rod, at a given angle; that action caused a reaction at the guide-bars, which tended to lift the engine. Now in engines with the driving-wheels at the end, the upward force, which was transmitted directly beneath the centre of gravity and tended to lift the engine, was, evidently, more controlled by the weight, than when it was transmitted to driving-wheels immediately in the centre, upon which the mass could vibrate and on which the weight would not act so directly. In consequence, however, of the expression of Mr. Stephenson's opinion, that the hind part of the engine was the worst position for the driving-wheel, on account of the angular thrust of the rod having a tendency to produce oscillation, he had made some experiments, which had confirmed his previous views. He must, therefore, contend, that his system did induce greater steadiness of motion.

Mr. R. STEPHENSON, M. P., *V. P.*, explained, that he had merely urged that as one of many reasons; but he had distinctly stated, that he considered the mode of communicating power to the wheels

was almost a matter of indifference. His objection to the driving-wheel being at the end, arose from other and more important considerations; he, therefore, objected to his argument being applied to a point which was really so unimportant.

Mr. P. W. BARLOW, through the Secretary, said, that he had examined the engine on the South-Eastern Railway which had been altered by Mr. Crampton. It was similar in construction to the 'White Horse of Kent,' (generally known from the Report of Sir C. Pasley,) with outside cylinders, and the driving-wheels in the centre, the six wheels being situated within the cylinder and fire-box. This arrangement had been justly condemned, by Mr. Stephenson, for its great oscillation, which caused so much wear, that after running 16,000 miles, the axle-boxes and bearings required a thorough repair, and moreover, great injury was inflicted on the permanent road.

The alteration, made by Mr. Crampton, consisted in placing the driving-wheels behind the fire-box, and the cylinders near the centre of the engine, by which arrangement the oscillation was so much reduced, that in the present engine, after running 16,508 miles, there had been little wear in the brasses, and the engine was perfectly steady, at the highest speed. The steadiness evidently arose from the weights being at the ends of the engine, and from the greater distance of the wheels. There was more tendency to oscillate when the driving-wheels, as in the 'White Horse' class of engines, were in the centre, for they then acted as a point of suspension, and, consequently, the engine more readily received the oscillating motion, induced by the action of the outside cylinders. The position of the cylinders also, by the lifting motion produced by the action of the steam, assisted the oscillation, as well as the tendency to run off the rails; whereas in Mr. Crampton's arrangement, the cylinders being situated nearer the centre of the weight, the whole engine was lifted, instead of one end, and these evils were avoided.

Outside cylinders produced a greater tendency to oscillation, than inside cylinders, by propelling the engine alternately at each extremity of the axle, the power being conveyed through the axle to the opposite wheel, but, from the great steadiness in Mr. Crampton's arrangement, it was evident, that this tendency was, practically, of little importance.

Mr. CRAMPTON regretted having taken a wrong view of Mr. Stephenson's argument. The principal objection to the plan was, he understood, that the relative position of the cylinders and driving-wheels, and the angle of thrust of the rod upon the rail, had a tendency to produce oscillation, and in fact, no other reason had been

urged against the driving-wheels being placed behind the fire-box. Conceiving these objections to be rather arguments in favour of his plan, he put the front wheels of one of his engines on to a weighing-machine, and took the weight; he then turned the steam into the cylinders and found a variation of 6 cwt. An engine, having the driving-wheels in the centre, was then subjected to the same trial, and showed a difference of 24 cwt.; now he argued from this, that an impediment in the road would more seriously affect an engine, with the driving-wheels in the centre, than one having the driving-wheels at the end, and he thought the effect of the steam was an important consideration in the question. He submitted, that however well a line was constructed, there must always exist impediments, almost amounting to a series of undulations, and, if there was too much weight on the centre wheels, when on a high part of the road, there was a tendency to lift the front wheels off; but with an engine having the driving-wheels at the end, the state of the road was less important, inasmuch as the weight on the wheels remained the same; the main point was, that the engine should travel along, without varying the condition of the bearing-weights on the wheels. It was shown, from Mr. Stephenson's engines, that increased length produced steadiness; for in altering an engine, the driving-wheels had been thrown a little behind the centre of gravity, small wheels being, at the same time, placed behind the fire-box, thus increasing the length to 16 feet, and giving greater stability. There was no doubt, that increased length gave steadiness; but Mr. Crampton contended, that it could be attained, without that objectionable extension of length.

The 'Iron Duke,' weighing 35 tons, travelled at the rate of seventy miles an hour: it had, however, eight wheels to give it length and steadiness, and if it was requisite to increase that weight, another pair of wheels would be necessary to prevent the bearings from heating. The 'Liverpool,' of the same capacity, had only six wheels, and he thought an engine might be constructed, of 20 tons weight, sufficient for all purposes, but not upon eight wheels, length not being so much required for steadiness as a low centre of gravity, and throwing the weight on the extreme ends. The 'Iron Duke,' 18 feet in length, ran steadily, as also did its tender with only 12 feet between the bearings. An engine, built by Mr. Stephenson, had the same proportion for the engine and only 11 feet between the bearings of the tender, and yet it ran steadily. Nearly every engine with six wheels had a tender on only four wheels, with 9 feet between the bearings, and Engineers never put a greater weight in the centre of the tender, if it had six wheels. He concluded, therefore,

that what would hold good for the tender and carriages, would apply also to the engines.

It appeared to him, that the steadiness was shown by the wear of the flanges of the wheels and the brasses of the bearings, and on the engine on the Dover line, to which reference had been made, the lateral wear on the brasses could hardly be perceived. By the position in which the driving-wheels were placed, the long bearings, which were now generally appreciated by Engineers, could be obtained. The whole of his statements, he thought, proved that, by his plan, it was possible to produce, for the narrow gauge, an engine of as great power as on the broad gauge, and, in fact, of greater power than could ever be required for the traffic, having, at the same time, as low an angle of stability and an equal amount of heating surface, without lengthening the boiler. The gearing was also entirely placed outside, which was not the case with other outside-cylinder engines; and he contended that it must be advantageous, both for cleaning and repairing, independent of the opportunity it afforded, for inspection and immediate access, in case of accident.

Mr. R. STEPHENSON, M.P., *V.P.*, repeated, that he did not consider the observations he had made, relative to the connecting rod, as bearing, in an important degree, on the question of steadiness. Mr. Barlow's statement, of the condemnation of a certain construction of engine, was not correct. He thought at the time, that, as compared with other engines, the one referred to might not have been quite so steady, as if the weight on the wheels had been otherwise apportioned, and he had said, that the proper adjustment of the weight was a most important point. With regard to the covering of surface, the 'White Horse' had a greater base on the rail, than almost any engine at that time in use. Immediately after the saving of fuel ceased to be the chief object, it became necessary to supply engines for travelling at a high speed, and at first, the engines of that class were not so steady as they had been subsequently rendered. He was anxious, also, to avoid its being taken for granted, that engines with outside cylinders were unsafe, and Mr. Barlow appeared to him to have totally misconceived the cause of oscillation. It arose from the momentum, or vis vivida, of the mass of the side gearing, &c., and the action of the steam had clearly no influence in producing it.

Mr. BIDDER wished to bring the discussion back to the principle laid down by Mr. Crampton, that the steadiness depended on the driving-wheels being placed behind the fire-box, and the weight being comprehended between the extreme wheels. Every Engineer recollected the old six-wheeled engines with inside cylinders and

cranks, in which arrangement the centre of gravity was necessarily high. He had himself travelled on those engines many thousand miles, at the highest speed they could attain; and in spite of the driving-wheels being in the middle, they were the steadiest engines he had ever travelled on. Bury's four-wheeled engines, having short bearings, were not so steady, when any considerable speed was attained; but when they were connected with the tender, and the weight on the rails thus became more equalized, they were found to be as steady as any other engine of equal length; it was evident, therefore, that steadiness depended on the length of area of railway covered. The question simply resolved itself into this:—whether the action of the steam, as communicated through the cylinder, acted with less power, in twisting the engine, or causing it to oscillate, when the wheel was placed behind, than in any other position. If this point was considered, without reference to the action of the steam in the cylinder, it would be seen, that the driving-wheel behind had a greater tendency to hammer the rails, than it had when placed in the centre. The springs acted more efficiently, in the latter case, than in the former; if the driving-wheel was in the middle, any inequality in the rail would be, to some extent, compensated for by the springs on the fore and hind wheels. He must contend it was obvious, that the effect of having the weight on the hind driving-wheels, would be injurious both to the rails and to the wheels.

The old engines, to which he had referred, had the cylinders in the smoke-box, and these engines were remarkable for their steadiness. The Great Western engines, in which the cylinders were similarly placed, were equally steady; he had travelled on them and on one of the old six-wheeled class, at the rate of sixty-five miles an hour, with the greatest steadiness. It was, therefore, incorrect to say, that the steam, as steam, had any effect; it was the unbalanced weight of the connecting rods, vibrating backwards and forwards, that produced unsteadiness. Several engines having six wheels, four of which were coupled, were unsteady until the weight of the connecting rods was perfectly balanced, when they immediately became steady.

The question to be discussed was, whether there was any particular virtue in having the driving-wheels behind the fire-box, and placing the greatest weight at the extremity of the engine. After all he had heard and seen, he thought there was no advantage in such an arrangement, and that, with regard to the hammering on the rails, it was the worst position in which the driving-wheels could be placed, as they followed all the inequalities of the rails. There was no doubt, that within certain limits, the length of the carriages

increased their steadiness. In altering the South Eastern engine, which had been alluded to, by simply placing a pair of wheels behind the fire-box and lengthening the bearings, thus bringing the weight in the centre, the steadiness of that engine had been materially increased.

Mr. CRAMPTON said, that Mr. Bidder's objection to the driving-wheels behind, on account of their following all the inequalities of the rails, was not well founded; on the contrary, he contended, that it was advantageous they should do so, and that it was a better system, as it enabled a constant weight to be maintained upon the driving-wheels, which could not be the case, when they were intermediate between the bearing-wheels, and had been adjusted to take their weight upon a part of the line in perfectly good condition.

Mr. R. STEPHENSON, M.P., *V.P.*, in answer to a remark from Mr. Crampton, stated that the reason for an extra pair of wheels being put on some of his engines was, not because they were unsteady, but because it was supposed the permanent road was suffering, and it was attributed to the weight on the driving-wheels; the extra wheels were being added for the purpose of relieving the permanent way.

Mr. CRAMPTON believed, that the chief cause of injury to the permanent way, was the unsteadiness of the engines. Mr. Stephenson's engine, (Fig. 4,) was similar to Mr. Bury's, with respect to the overhanging fire-box; surely that expense might be saved, if by coupling it to the tender, the same purpose was answered.

Mr. BRUNEL was anxious that the Institution, as a body, should not pronounce any opinion on the subject before them; and he hoped, that the observations which had been made, would not be considered as the final arguments for, or against any particular point, raised during the discussion. He thought, that undue advantage had been taken of chance expressions made by some of the speakers, in order to induce the belief, that those were the sole arguments which could be urged. Mr. Brunel wished particularly to guard himself from having it supposed to be his opinion, that there was any disadvantage in making a load rest on two points instead of on three; he believed, on the contrary, that, cæteris paribus, a load would be carried steadier, when resting on two points, at each extremity, than when resting on three, or four points. All he had said was, that six-wheeled engines, with the driving-wheel in the centre, had run very steadily, and he did not think there was any unsteadiness caused by the greater weight being placed in the centre. The case put by Mr. Crampton, where the weight in the centre was supposed to be twenty tons, whilst there

was scarcely any at the extremities, was an arrangement which he could not conceive to be possible, nor was it easy to predicate the motion of an engine, under those conditions; one thing was, however, certain, that such an engine would not run steadily. His own experience had led him to believe, that for various reasons connected with the framing of the engine, and the general detail of the construction, it was better to place the driving-wheel in the centre, than at the extremity; indeed, he could not see any real advantage in placing the driving-wheel at the extremity. Taking into consideration all the causes in operation, when an engine was running, he did not believe, that throwing an excess to the extent of ten tons over five tons, at the extremity, could make the engine steadier, than if the driving-wheel with ten tons on it, was placed in the centre, and five tons at each end. He did not feel, that any of the arguments used had proved, or that the diagrams exhibited, contained convincing proofs of that construction having made the engine steadier. Mr. Barlow had merely shown, that an engine had been altered, in order to render it more steady. Mr. Brunel had understood, that the engine represented in Fig. 3, being unsteady, had been altered to the shape given in Fig. 4, when it became steady, in consequence of the driving-wheel being placed behind, and he had remarked at the time, that the engines were not the same, and that the diagram exhibited could not be correct. He assumed the 'Iron Duke' to have twelve tons on the driving-wheels, and five tons on the other wheels, and that engine ran perfectly steady, and he did not believe, that any alteration in the position of the wheels could make it steadier.

With respect to the experiments he had made on the carriage with four and with six wheels, he only quoted them as a proof, that there was no great importance in the circumstance of some of the weight being thrown on the centre wheels. To try the comparative steadiness of different-shaped tires of wheels, he had, some time ago, constructed some common trucks, with a lump of cast iron, weighing half a ton, at each end, working in a frame, so as to enable each to be raised and lowered, and he expected, that by raising those lumps to a considerable height beyond the bearing of the wheels, the stability of the carriage would be altered; his experiments, however, failed, as he could not succeed in making an unsteady carriage. He thought the great cause of oscillation was from the piston and the momentum, or vis vivida, of the piston and of the connecting rod in rapid motion, on each side of the machine.

Mr. Crampton observed, that the diagrams were simply drawn to illustrate the general principle of the machines, and that the

same distance had been made between the extreme wheels, in order to show them under the same circumstances. Some, of course, might be longer, and others shorter; but in neither case did this circumstance interfere with the principle on which the engine was constructed.

Mr. Locke, M.P., agreed, that great care should be taken, lest the opinions expressed at the Meeting, should be considered to be those of the Council of the Institution, or of the body of Engineers generally. He thought it necessary to make the remark, as he entirely disagreed in the opinions expressed by Mr. Stephenson and sanctioned by Mr. Brunel, with reference to outside-cylinder engines.

Major-General Sir C. Pasley said, that in the course of his investigations into the various systems of construction of locomotives, the great difficulty appeared to be in producing engines for the narrow gauge, equally steady and capable of competing with those on the broad gauge. Now he thought by Mr. Crampton's plan of construction, this desideratum might be attained, and he must contend, that there was great merit in the arrangement which permitted the axle of the driving-wheels to be placed behind the fire-box. It was considered a great advantage to have high driving-wheels, and by Mr. Crampton's system, while their diameter could be increased almost indefinitely, the centre of gravity of the boiler was actually lowered. The power and speed of an engine depended, in a great degree, on the width and capacity of the fire-box, and on the ordinary gauge of 4 feet 8½ inches, the requisite width could not be obtained, except in the mode recently adopted by Mr. McConnell, who, in a large engine on the North-Western Railway, had increased the distance between the hind and the driving wheels, to enable the fire-box to project laterally, so as to obtain almost equal capacity, to those of the engines of the broad-gauge lines, obtaining, at the same time, a boiler of much greater evaporating surface. General Pasley was not aware, whether that engine had ever made a journey; but if it was successful, it would, he thought, equal any of the locomotives on the broad-gauge line, which ran safely and well. The gauge of 5 feet 3 inches proposed by him for Ireland, would, if it had been adopted, have enabled the engines to have had fire-boxes and boilers of the same dimensions as those which originally conveyed the express trains on the Great Western Railway.

After reviewing the origin and progress of the locomotive engine, General Pasley stated, that the locomotives first used had only four wheels; Messrs. George and Robert Stephenson had the merit of bringing them into general use, in a form capable of doing work;

Mr. Bury had also made similar engines, but General Pasley considered them decidedly unsafe. In 1844, when he first saw Mr. Robert Stephenson's engines with long boilers, he reported on them favourably; and in September 1845, it having been urged on the Government, that owing to the rivalry between the railway companies, the speed of express trains ought to be restricted by law, he was directed by Lord Dalhousie to report on the subject. He had, in consequence, travelled on the engines of the express trains of every railway in the kingdom, and although he had not been called upon to make an official report, yet the result of his inquiries was, that no ground existed for apprehending danger from the speed; but that Mr. Robert Stephenson's long-boiler engine, similar to the 'White Horse of Kent' was unsteady and unsafe, if pushed to a speed exceeding forty-five miles an hour. On the 19th of December, he gave a similar opinion before the Gauge Commissioners, adding, that Mr. Robert Stephenson had produced a long-boiler engine having two pairs of wheels coupled, which he considered perfectly safe. He had never made any sweeping condemnation of the long-boiler engines, but on the contrary, he was inclined to think well of them. In consequence of an accident which happened to an engine of that class near Thetford, he had cautioned the Company against urging them at great speeds; and although it had been said, that as a military man, his opinion was not entitled to much weight on such subjects, yet, since that time, so many accidents had happened with engines of that sort, that he contended his opinion had been fully borne out. Among other instances, he would mention that which occurred on the 1st of January 1846, when an engine made by Messrs. Kitson, on the 'White Horse of Kent' pattern, with inside cylinders, rolled over, when Mr. Bidder was in the train. He thought Mr. Stephenson's original plan, of placing the axles of the wheels so close together was erroneous, and that Mr. Brunel's engines, with the centres of the wheels, at from 16 feet to 18 feet apart, were decided improvements; and like those constructed by Mr. Crampton, with the driving-wheels behind the fire-box, they were perfectly steady. He had seen a tender with four vertical helical springs, which he much objected to; it pitched about like a ship at sea, and the stoker was obliged to watch his opportunity to throw in fuel.

Mr. R. Stephenson, M.P., *V.P.*, said, that although he deprecated rendering the Institution an arena for anything approaching to personal discussion, the gauntlet had been so pointedly thrown down with respect to the long-boiler engines, that he must notice it; at the same time, he would preface his remarks by saying, that all

the opinions emanating from General Pasley had invariably received the utmost attention from him, as his Reports bore the evident impress of honesty and gentlemanly feeling; but when the question was purely mechanical, Mr. Stephenson must be permitted to retain his own opinion, however widely it might differ from that of the General, and he believed the Institution would so far coincide with him.

Now with respect to the engines under discussion: in spite of the General's commendation of the driving-wheels of large diameter, placed behind the fire-box, Mr. Stephenson's experience of the working of railways induced him to doubt whether the system had not been carried too far. In the North, the diameter of the driving-wheels was being reduced, with advantage to the speed of travelling, and on every line, using large wheels, where the stoppages were frequent, it would be found, that more loss of time occurred in starting, than if smaller wheels had been used, and that the entire journey was not performed so steadily. Indeed, he was not at all persuaded, that high wheels would be maintained in the South, where light trains and few stoppages were required. The size of the wheels of an engine depended, not on the utmost speed to be attained, but on the number of times the train stopped and started, between two points. When the Great Western Railway originally applied large wheels, it was found, that more time was absorbed, than by the smaller wheels, even considering the great speed of the engine. There was a given proportion, in all cases, between the number of stoppages and the speed of the piston, to accomplish a stated distance between two points, in a given time; now in order to obtain the greatest amount of power with the least weight, the piston of the engine must be driven at the utmost speed. At one time, an attempt had been made to reduce the speed of the piston as much as possible, it was, however, now found, that the utmost speed was desirable. Mr. Stephenson did not attach any importance to the size of the wheels, and as to lowering the centre of gravity, the statement made by Mr. Brunel showed, that beyond certain limits, a low centre of gravity was not necessarily productive of any beneficial effect, and from his own experience he conscientiously confirmed that opinion. He had lately travelled, with the utmost steadiness, on an engine whose centre of gravity was at least as high, if not higher, than any he had previously seen. He therefore totally denied the correctness of the points urged, first, as to the great advantage of high wheels, and next, as to the steadiness of an engine being entirely caused by an extremely low centre of gravity.

Mr. Bidder said, that the accident to which General Pasley had

alluded, was simply that the engine ran off the line, in consequence of a broken chair; no damage ensued, and the engine was worked within three days of the accident, without one shilling having been expended on it. With respect to the locomotives on the Norfolk line, notwithstanding the General's advice, they had been run faster instead of slower; and the only preparation for the increase of speed was, that the engine and tender had been coupled, which had the effect of extending their base on the rail: this system had been followed for four years, and there had not been an accident.

Mr. HOMERSHAM called attention to an engine altered by Mr. Crampton, in which the centre of gravity was raised about two inches, but which when altered travelled much steadier than before; whilst an engine of a similar construction unaltered, was still very unsteady. This showed, that a low centre of gravity did not, as had been stated, necessarily produce steadiness; but it did appear, that placing the greatest weight at each end of an engine was an important point in giving stability, and the plan of doing away with any overhanging weight was manifestly advantageous, for engines travelling at high velocities.

Mr. BERKLEY said, he had travelled on an engine of the 'White Horse of Kent' class, which, as long as it had a great weight overhanging the wheels, was certainly not steady, but the addition of a small pair of wheels, behind the fire-box, gave it the most perfect steadiness.

Mr. CRAMPTON said, he had always admitted, that the extension of the base must induce steadiness, but he denied, that it was essential to that quality; on the contrary, he knew many short engines that were perfectly steady, and perhaps the best instance was that of Mr. Samuel's small engine, on the Eastern Counties Railway, which, although only having four wheels, at 9 feet apart between the centres, ran at high speeds, with remarkable steadiness. The centre of gravity was certainly very low, as the whole machine was kept as close as possible to the rails: he must, however, contend, that it showed an extended base was not indispensable for steadiness. He must also contend, that much of the question depended on the state of the permanent way, for if the joints were in such condition as to produce sudden jerks, no engine could travel steadily, under any circumstances: he apprehended, however, that undulations would occur on the line, and any machine, which varied its weight upon the driving-wheels, must injure the surface of the rails. Mr. Hawkshaw's permanent way appeared calculated to reduce much of the irregularity of surface, and would, therefore, be very advantageous, both for the engines and for its own duration.

Now, however small, or great these undulations of surface might be, he contended, that the driving-wheels behind must adapt themselves better to them, than the wheels at, or near the centre. He admitted, that the height of the centre of gravity, (within certain limits,) was not of such importance as the objectionable scale-beam action, arising from the position of the driving-wheel near the centre. The lowering of the centre of gravity, however essential, was not of the importance of other points, embraced by his engine, particularly that of bringing the weight on the extremities, when travelling on an undulating line. He must be permitted to say, that the opinions, rather than reasons, which had been given against his system, had not been at all convincing to him; and he thought the Meeting would coincide with him, with respect to the position of the driving-wheels, the angle of thrust of the connecting rod, and the facilities for construction, inspection, and repairs.

Major-General Sir C. PASLEY agreed with Mr. Locke, in his opinion of engines with outside cylinders; he had travelled on many of them, and the unfavourable impression of them, which he originally entertained, had been entirely dispelled, by his experience of the regularity with which they did their work, and their steadiness at high speeds. He thought it was to be regretted, that Mr. Stephenson, who originally used outside cylinders, had not continued to employ them, for if his attention had been directed solely to that construction, he would, doubtless, have produced some very superior machines of that class.

With respect to the boilers, he had seen as good speed kept up with tubes of 10 feet 6 inches in length, as with the long boilers.

Mr. R. STEPHENSON, M.P., *V.P.*, reminded Mr. Crampton, that the large wheels on the Great Western Railway had been abandoned, on account of the difficulty of getting up the speed of the train. The engines had, originally, wheels of 10 feet diameter, but many were now reduced to 7 feet diameter. In the north of England, the large wheels were being taken off many of Mr. Stephenson's engines, and smaller ones were being put on, for the purpose of saving time in the journeys.

Mr. BIDDER observed, that in the gauge experiments, which had been referred to, the narrow-gauge engine had smaller wheels and cylinders, and the total power of generating steam was 10 per cent. less than the broad-gauge engines; but with the same train behind them, although on a long journey, the broad-gauge engine had the advantage in speed, yet for the first seven, or eight miles, the narrow gauge obtained a greater velocity. The reason was, that at a high velocity, neither engine could keep the steam up to the full pressure

on the cylinders, but they could do so at starting, when the revolutions were slow. The effect was, that the lesser wheel went round four times, whilst the larger only made three revolutions. Thus the cylinders were four times filled with steam, and nearly one-fourth more power was brought into action to urge the train forwards; therefore, until such a considerable speed was attained, that the boiler could not supply the cylinders with the full pressure of steam, the smaller engine had the advantage. When both engines got into full play, the broad-gauge engine regained its advantage and overtook the other.

Mr. CRAMPTON said, that trains could be started with large wheels as well as with small wheels, and that the fact of the reduction of the diameter of the wheels on lines in the North, having enabled the trains to get more quickly into speed, was no proof that small wheels were preferable. It must be remembered, that the cylinders still remained of the same size, and the reduction of the wheels only induced more tractive power on the periphery of the wheels; now had the cylinder been increased so as to produce the same relative tractive power on the circumference, precisely the same result would have been arrived at, and with this advantage, that in consequence of the greater diameter of the wheels, the friction would be less.

With regard to the remarks respecting the gauge experiments, he thought they merely showed, that the engine with small wheels had more tractive power at the periphery of the wheel, in the ratio of 4 to 3; this would enable it to start quicker, but did not prove, that small wheels were better for general use than large wheels. It appeared to him, that with a given boiler, the power transmitted to the periphery of the wheel would be the same, with wheels of all sizes, provided the same proportions existed between the cubic contents of the cylinders and the diameters of the wheels. It was owing to this circumstance, that the engines, with wheels 10 feet in diameter, on the Great Western Railway, did not start so readily as the 'North Star,' with wheels of 7 feet diameter; in fact the former engines had only 450 feet of heating surface in the boiler, whereas the 'North Star' had 800 feet of surface: the cylinders, in both cases, being nearly proportioned to the boilers. After this experiment, about twenty engines were made, with wheels 6 feet in diameter, and an equal number, with wheels of 7 feet diameter, and so decided was the superiority of the latter, over the former, that for the last six, or eight years, no engine had been used, with wheels of less than 7 feet in diameter; on the contrary, they had been increased to 7 feet 6 inches, 8 feet, and even, he believed, to 8 feet 6 inches.

It had been said, that in 1830, the stroke of an engine, on the Liverpool and Manchester Railway, had been reduced from 18 inches to 12 inches: this did not agree, in principle, with a marine engine constructed for Her Majesty's service, in 1848, by Messrs. Maudslay and Field, in which the diameter of the cylinders was 48 inches, and the stroke was 22 inches, and of which the duty was quoted as very good.

There were three principal motions in the locomotive, arising from the weight on the wheels, and the height of the centre of gravity; the vertical action gave the greatest motion, the weight being on the centre wheels, and when they came to the high parts of the road, so little weight was on the ends, that a pitching, or scale-beam motion was produced: when in this state, the lateral irregularities of the road, shaking the front wheels, caused a side motion, and these combined gave a serpentine motion to the machine; moreover, when the centre of gravity was high, these motions were greatly augmented. Now when the weights were placed on the extreme ends, there was an absence of all vertical and lateral motions. If the centre of gravity was high, heavy side-lurches would occasionally take place, from the irregularities of the way: this induced Mr. Crampton to insist upon a reduction of the height of the centre of gravity, which was very easily effected, in combination with the other advantages offered by his system of construction.

Mr. Henry Maudslay observed, that nothing had been said as to the proportionate length of stroke. He wished to ask, whether if, instead of diminishing the diameter of the wheel, a proportionate increase of length of stroke had been given, a great advantage in starting would not have been obtained?

Mr. R. Stephenson, M.P., *V.P.*, thought Mr. Maudslay had started an interesting point; the proportion of the length of stroke, to the capacity of the cylinder, had not, he believed, been yet correctly ascertained. He remembered an experiment being made, on the Manchester and Liverpool Railway, at a very early period, when to diminish the supposed loss from the reciprocating action, the diameter of the cylinder was increased and the length of stroke was diminished, still retaining the same size of driving-wheel. It was found, that the old tender which formerly sufficed for the journey, would not go more than half way, and the consumption of water and fuel appeared to be in the direct ratio of the increase of diameter of the cylinder; a result the reason of which, however, he confessed himself at a loss to account for satisfactorily.

Mr. Crampton said, that his practice was, to obtain the best ratio of proportion between the capacity of the cylinder, the length

of stroke and the diameter of the driving-wheel, and to maintain those proportions, in order that, under all circumstances, the utmost useful power might be obtained.

May 1, 1849.

JOSHUA FIELD, President, in the Chair.

THE following Candidates were balloted for and duly elected:—Richard Peacock, and William Wilson, as Members; William Eagle Bott, Captain Henry James, R.E., and William Sowerby, Junior, as Associates.

The discussion upon the Paper, No. 794, "On the Construction of Locomotive Engines, &c.," by Mr. T. R. Crampton, being renewed, was extended to such a length as to preclude the reading of any other communication.

May 8, 1849.

JOSHUA FIELD, President, in the Chair.

No. 805.—"Description of the Permanent Way, of the Lancashire and Yorkshire, the Manchester and Southport, and the Sheffield, Barnsley, and Wakefield Railways."* By John Hawkshaw, M. Inst. C.E.

THE rails are laid on longitudinal timbers of Canadian yellow pine, 14 inches broad and 7 inches thick, each piece of longitudinal timber being sawn, on its upper surface, to the angle corresponding to the transverse inclination intended to be given to the surface of the rails, viz., 1 in 20. Cross-sleepers of the same timber, 12 inches broad, 4 inches thick, and 8 feet long, are bolted under the longitudinal timbers, at every joint of the latter. These cross-pieces not only serve to support the joint of the longitudinal timbers, but they also help to keep the two rails forming one line of way, in the same plane transversely, a desideratum when the road is lifted by the plate-layers. The rails used are of the bridge form, 75 lbs. per yard, and malleable iron plates, or chairs, 14 inches long, 8 inches broad, and ½ an inch thick, are placed under each joint. The rail is bolted down to the timber, at intervals of 24 inches.

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* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

The chief point of difference, between this and the other modes of constructing permanent way, consists in the rails being riveted to the joint-plates, so as effectually to prevent motion at the joints, and also to insure a more uniform deflection along the rails.

The rails and the joint-plate are riveted together at each joint with eight ¾ inch rivets. To allow for contraction and expansion, and also for the slight irregularity which, in practice, is found to occur between the holes in the rails and those in the chair, or joint-plates, the holes in the joint-plates are made 1 inch in diameter, or ¼ of an inch larger than the rivet. In riveting, care is taken to heat one end only of the rivets, which is effected by passing them through a plate of iron, punched for the purpose, which protects the head and a part of the rivet from the fire.

Several miles of this road are now laid, and portions of it have been run over during nearly twelve months; and it appears, at present, to answer very well.

The Paper is illustrated by two drawings, (Nos. 4,450 and 4,451.)

Mr. HAWKSHAW explained, that the nature of the joint used was the principal novelty in this mode of laying the permanent way: for many years past, he had used both the continuous bearing and cross-sleepers, but up to within a comparatively recent period, he had employed the latter system in preference; he thought, however, that for high speeds, a better road could be made with continuous bearing longitudinal timbers, than with cross-sleepers. Formerly, he used as the fastening for the cast-iron joint-chairs, short bolts, the heads of which were countersunk at the under-side of the chair, and the nuts were screwed on from the top-side; he found, however, after some time, that the screws became so corroded, that they were obliged to be cut off, when it was necessary to remove them, so that there was neither economy, nor facility afforded by their use; he had therefore dispensed with the screws and nuts.

In laying a line, it was an important point to prevent there being any greater amount of deflection at the joint, than at any other part of the rail, and he thought the best way of doing that, was to unite the two abutting ends of the rails, in such a manner as to be exactly equal in strength to the body of the rail itself; he therefore adopted the wrought-iron plate-chair, with a projection on the upper side, fitting into the cavity of the bridge-formed rail, and having such a large bearing surface on the timber and such a length for attaching to both rails as rendered the joint as strong as the

other parts of the rail. In order to provide for proper contraction and expansion, he used, as fastenings for the rails to the chair, wrought-iron rivets ⅛ths of an inch in diameter, exactly filling the holes in the rail, but having some play in the holes of the chairs. Twenty miles of line, thus laid, had recently been carefully examined, and in the whole of that length only three rivet-heads were found to have been knocked off; whilst the rest of the joints were as good as when they were first laid down. The arrangement of the longitudinal and transverse timbers might be varied to any extent: the first he laid, had cross-sleepers at intervals of 6 feet, or 7 feet, and on another line, the longitudinal timbers were simply connected together by tie-bolts. One great advantage of the present plan of placing the cross-sleepers was, that it prevented the twisting of the longitudinal timbers, which frequently occurred, when the platelayers were packing the permanent way. He thought, that longitudinal timbers would last longer than cross-sleepers, from their being laid nearer to the surface of the ground, so as to be dried by the air, and he made a point of keeping their surfaces clean, and properly drained. This system of construction was rather cheaper, as less iron was required, and two men would do as much, in repairing a line of that description, as three could do, upon a line laid on cross-sleepers. He had never yet seen any cross-sleepers which were good enough to receive a second set of rails, but these longitudinal timbers had done so. The line was certainly smoother for the traffic, and any impediments, from the rising of the ends of the rails which had been much talked of, would not be likely to occur.

Mr. SAMUEL said, too much stress could scarcely be laid on the importance of obtaining a surface, which, if not absolutely an inflexible plane, should be equally flexible throughout, and yet should not have any loose parts, on which the wheels should produce the effect of a blow. It was generally admitted, that there was a constant succession of blows, between the rails and the chairs, and that those blows were comparatively harmless in the intermediate chairs, but were very mischievous at the joints. The cause of this difference was, that where the rails abutted against each other, the resisting strength was probably less than one-fourth, either laterally, or vertically, that of the intermediate portions of the rails. Thus, however well the rails might be laid, if a rolling load travelled over them, of greater insistent weight than the joint-portion was capable of sustaining, the result would be, not a curve-like flexure, but a positive angle, of greater, or less depth, the action at the same time loosening the rails and keys in the joint-chair, and forming cavities

between the rails and the chairs, and also between the sleepers and the ballast. After the load had passed, the rails by their elasticity recovered their usual position, and the next rolling load produced a positive blow, tending to increase the depth of these cavities. If wet weather occurred, the water, getting in between the rail and the chair, induced corrosion, which was soon beaten off by the traffic, and the rain between the sleeper and the ballast softened the latter beneath the rail on each side. By a continuance of this action, the sleeper, being pressed down at the ends beneath each rail, and not so heavily pressed in the centre position between the rails, became a spring, and for the injury produced by this action there did not appear to be any present practical remedy; or, in other words, no method of rendering the sleepers firm in the ground by packing: because the density of the packing driven in by the plate-layer, was limited by the actual gravity of the sleepers and rails. When the wedging action of the packing was in excess of the total weight, the rails and sleepers were lifted. The piling principle, formerly resorted to by Mr. Brunel on the Great Western Railway, was an attempt to surmount the difficulty. Had the piles been close together, or had the longitudinal timbers been sufficiently rigid to prevent springing, it was possible, that the plan might have been mechanically successful, although, probably, not commercially advantageous.

The sinking of the sleepers between the rolling loads, which had been received as evidence of want of sufficient bearing surface, had induced the practice of increasing the number of transverse sleepers, and to this the only limit would be a solid platform, if heavy rolling loads were persevered with. The greater the number of the cross-sleepers, or, in other words, the greater the amount of surface, the longer, probably, would be the duration of the road. It was, at one time, the practice to use transverse sleepers at intervals of 5 feet; they were now laid at intervals of only 3 feet. Their dimensions were at one time 7 inches by 4 inches; they were now frequently 12 inches by 6 inches: this gave about 46 square feet of surface in one length of rail, or about 23 cubic feet of timber. If this amount of 1½ foot of surface to each foot-run of rail, could be disposed longitudinally under each rail, instead of being spread out beyond and between the rails, greater durability would be the result.

But in whatever way the timber might be disposed, it must be clear, that the greater the depth of the rail vertically, consistent with its lateral strength, the better the metal would be disposed to resist strains of deflection. In this view, the form of rail which had been adopted by Mr. Hawkshaw, which was similar to that of the Great

Western, was, in Mr. Samuel's opinion, defective, and the form known as the double T was preferable. This would appear more evident in considering the question of uniting the rails at the joints, in order to render them equally strong with the other portions. The depth of Mr. Hawkshaw's rail was 3½ inches; a double T rail, with the same amount of metal, was 5 inches deep: it was obvious, therefore, that the double T would sustain the load best. The chair or 'union' plate of Mr. Hawkshaw was broad and flat with a rising centre of only 1¼ inch in depth. In the system proposed of uniting the double T rail, the depth of the side-fishes was 3¾ inches, and in the cruciform rail with the deep centre, it was 5 inches deep. Again, the rivets of Mr. Hawkshaw's rail were subjected to a direct pressure, tending to shear off their heads, if the joint yielded, whereas in the other, the direct pressure was in the vertical direction of the fishes, producing, indirectly, an end tension on the bolts. The holes in the rails were oblong, to permit of expansion and contraction. The rails thus prepared were laid in cast chairs, with wooden keys in the ordinary manner, but the joint-chairs were altogether dispensed with.

A number of these fish-joints had been laid down, under Mr. Samuel's directions, between London and Stratford, and had been travelled over with heavy traffic, for a period of five months. Their utility was obvious, for on observing a heavy engine pass over the joints, the deflection was seen to extend over the whole surface of the rails, which weighed nearly 92 lbs. per yard, while the joint was equally as strong as the intermediate portion. The joints thus strengthened rendered the rails as perfect as when they were first laid down, while the joints that were laid in the ordinary manner were all loose, and the rail-ends were hammered out of shape, by the wheels of the engines.

The system of connecting the two rails together by the lateral fishes, had the advantage of obtaining equal strength throughout, and of preventing the rails from twisting in the chairs. There still remained, however, the disadvantage, peculiar to all rails of deep section as they were commonly used,—the height at which they stood above the base, which rendered them easily affected by the side lurches of the engine and carriages. To obviate this, Mr. Samuel had tried a new system, embracing the double T rail with longitudinal sleepers, without the use of chairs, or holding-down bolts. Two timbers, 7 inches square, were placed side by side, and in the matching sides a half groove was cut, corresponding to the form of the rail, and of such depth vertically, that the upper lip of the rail rested on the top of the timber. The two timbers were then bolted

together, so that the bottom of the rail bore on them laterally, at distances of 3 feet. In addition, a bolt of larger iron passed through the rails, one half in each, at the joint. The joints of the timber alternated with the rail-joints. Several lengths had been laid down on this plan, five months ago, on the Eastern Counties Railway, between Bow and Stratford, and the result, up to the present time, showed the system to be good, although the work was hurriedly done, and the joints were not fished.

Another form of rail, of deeper vertical section, illustrating the same system, gave about 40 feet of direct bearing surface, being a larger amount than by the mode of cross-timbers before described, with about the same cubic content of timber.

In this mode of construction there were fewer parts, than with the system of rails, chairs, and keys; in fact, the system was one continuous wooden chair. A length of one pair of rails on the cast-iron 'chair system,' required—10 chairs, 20 spikes, 10 keys, 5 sleepers, 2 rails, 4 fishes, and 8 bolts—total, 59 pieces; whereas the improved plan only required—4 longitudinal timbers, 1 cross-timber, 2 rails, 1 tie-rod, 10 bolts, 4 fishes—total, 22 pieces, or less than one-half the number. But as there were no loose keys, the risk from a displacement of rails was materially reduced, and in case of the wheels leaving the rails, they would probably run a considerable distance on the longitudinal timber, without any abrupt blows.

The cost of a length of 15 feet of this cruciform rail would be £6, or £2,112 per mile of single line, which was about the same as the cost of an equal length of the transverse system with chairs.

Mr. BRUNEL said, it was well known he was an advocate for longitudinal sleepers, having always adopted them, and having had, during the last ten years, much experience in their application. He agreed with Mr. Hawkshaw, as to the necessity of providing a solid resistance at the joints: when that was assured, he thought the principal difficulty was overcome, and that a different form of rail would not offer any great advantage. Some of the objections to longitudinal rails would be met, by giving a great depth to the rail itself; at present, the only one, he thought of any importance, arose from the creeping motion, produced by a rolling weight over an elastic bar of iron. The advantages of longitudinal timbers were, that they produced more safety and less liability to destruction to the rails and carriages, when there was any derangement of the permanent way, and that the wheel of an engine, or carriage, when off the line, continued to run on the flange of the rail, or the timber: such cases had frequently occurred, in consequence of bent, or broken

axles, without producing any material injury, until the train was either stopped, or had arrived at a station. He thought also, generally speaking, that they were less liable to derangement from sinking, that they were more easily kept in a proper state for running upon, and that it was easier to maintain a perfect joint in a rail resting on a continuous timber, than when resting on chairs.

He had experienced the difficulty which had caused Mr. Hawkshaw to rivet his rails to the plates. In order to obviate it, Mr. Brunel had placed the ends of the rail on a plate rather larger in size than that used by Mr. Hawkshaw, with a sufficient bolting power, to press it into the timber; he applied two large bolts, at the end of the rail, and two others, at a distance of about 12 inches, or 18 inches. After a few days' traffic, the plate, which was about $\frac{3}{8}$ths of an inch thick, was squeezed into the timber, and the surface became perfectly level; that method produced a sufficiently firm joint, and a good permanent way. He had not found any inconvenience to arise from the timbers turning on their axis; the transverse timbers were slightly let into the longitudinal timbers, and firmly bolted, giving a bearing surface of 7 inches deep against the side: this was repeated, at intervals of 12 feet, and produced sufficient stiffness to prevent the turning of the longitudinal timbers. Originally some difficulty had arisen, from the rails not being placed exactly in the centre of the timber; but latterly, he had caused the timbers to be slabbed and the rails centered, the transomes being bolted to them, and there was no longer any tendency to twist. He was averse to placing the transomes underneath the timber, as in lifting them, the men were liable to let loose ballast fall into the space they occupied, which was, of course, injurious. He thought the objection urged as to the rivets being liable to be sheared off, was not founded in practice, but it was certainly singular, that Mr. Hawkshaw should have succeeded in riveting up a great length of rails without being inconvenienced by their contraction, or expansion. On the Great Western Railway, from eighty to one hundred rails had been welded together, for the last four, or five months, but there not having been any hot weather in the interim, he was unable to judge of the eventual results. The men engaged in the maintenance of the way had assured him, however, that rails which had been originally laid down at distances of $\frac{1}{4}$th of an inch, had been rolled out by the passage of the trains, so that they were now close together, and that there was a perceptible difference in the effect produced by the trains on a hot, or cold day. He was, therefore, afraid, that in hot weather, the expansion would lead to considerable undulation.

He thought the bridge-rail, used by Mr. Hawkshaw, was better

than the T-shaped rail: he also thought the double-headed rail would not afford a sufficient bearing surface, though it required further time to ascertain its value. He had paid much attention to the manufacture of rails, and he thought it would be difficult to straighten those of the form proposed, on account of the mass of metal on the upper side being so much greater than that on the under side. He had adopted rails of from 60 lbs. to 65 lbs. in preference to heavier ones, for various reasons, one of which was that a rail of that weight was better manufactured, and could be made of better metal. The modes of making rails were continually changing, and it was, therefore, possible, that the proposed form of rail might be well manufactured; but at present, he approved of a rail like that used by Mr. Hawkshaw, with good plates at the joints, and secured permanently to the timbers. Wood screws would not do for that purpose; bolts with nuts underneath alone would prevent the creeping motion to which he had referred, and secure permanent adhesion. He considered the ordinary mode of laying rails on cross-sleepers was advantageous, so far as the drainage was concerned.

Mr. SAMUEL observed, that it was originally intended to put down the piece of railway referred to, with fishing-pieces, but sufficient time was not allowed; and he attributed the little motion, which was observable at the joints, to the want of those fishing-pieces.

Mr. P. W. BARLOW, from an examination of the piece of road laid down by Mr. Samuel, considered it to be the simplest and best construction, and he felt assured, that the use of timber-sleepers would soon be discontinued, by which the immense destruction of timber, which it cost half a million a year to renew, would be saved.

Mr. BRUNEL observed, that one great advantage in the use of longitudinal timbers was the great facility with which a rail could be taken up, and replaced; half an hour being sufficient for that purpose. He disagreed with Mr. Barlow as to the great destruction of timber, as from 1838 to the present time, the quantity replaced on the Great Western Railway was exceedingly small.

Mr. HAWKSHAW said he had laid rails on longitudinal timbers during ten years, and he had recently laid other rails on the same timbers, but cross-sleepers had not worn for the same length of time: the exposure of the former to the light and air tended, doubtless, to preserve them; and he believed, that they made the best road. He had no fear as to the results of the riveting, on which system he had laid down about ten thousand tons of rails; he had used plates at the joints with bolts and nuts, and the latter eventually became rivets, as they were found to be inseparable from

the bolts. Some time ago, he had riveted a cast-iron fence, 9 feet high, 800 feet long, and 1 inch thick, and although that fence had been standing for seven years, he had never observed any distortion in it during summer, or winter. He had used cast-iron sleepers for some time, but he preferred those made of wood, which he thought afforded an easier road, and were not so liable to be broken.

Mr. PIM said, that on the Dublin and Kingstown Railway, Dantzic timber was laid down thirteen years ago: in the course of the two, or three following years, the whole of the rails, (45 lbs. to the yard,) which had been originally laid on stone blocks, were relaid on longitudinal wooden sleepers of common pine, and coarse Memel; and in 1839, a large quantity of elm was used. Until within the last year the timber had not given any trouble, but since that time a good deal had been replaced, and the elm was found to have suffered the most. Some of the Dantzic timber which appeared sound was found to be rotten inside, whilst other portions which had rotted outside, were found quite sound in the middle. He thought the time occupied in replacing longitudinal timbers was a great objection to their use, more especially on the Dublin and Kingstown Line, where it was necessary to replace them by night, which was an expensive and unsatisfactory plan.

He had looked at the specimen of railway laid down on the Eastern Counties Line by Mr. Samuel, and he highly approved of it.

Mr. GORDON had no experience of the relative value of different kinds of timber on railways, but in the construction of ships, elm should only be used for the keel, and those parts which were constantly under water.

Mr. BIDDER said it should be remembered, that cross-sleepers were frequently made of Scotch fir, whilst longitudinal timbers had been generally made of pine, or Memel, and great pains had been taken, in the first instance, to preserve them; he thought, however, that they might all be beneficially employed, if they were carefully creosoted, and that no other material presented the same advantages as timber. He had creosoted about two thousand cross-sleepers of fir, on the Northern and Eastern Line, and specimens which were taken up two years ago were perfectly sound, although the adjoining ones, which had not undergone that process, were rotten. If Mr. Samuel's plan of fishing the joints should succeed, lines with cross-sleepers would be made quite equal to those with longitudinal timbers.

Captain W. S. MOORSOM said, that there was, originally, great prejudice against longitudinal timbers, but after many years' expe-

rience, he was convinced, that on the whole, they made the best road, that they were quite as capable of giving a firm bearing as cross-sleepers, and that they were much easier repaired when out of order; he would always lay them where there was any apprehension of sinking.

He had been influenced, no doubt, by what he had seen in the Dublin and Kingstown Railway, which was the oldest longitudinal line, although owing to the rails themselves and the bad method of fastening them, that railway could scarcely be quoted as a successful example. There was always a jarring motion, wherever there was a continuous bearing, whether of stone, iron, or timber, but he did not think, that it had any tendency to destroy the engines and carriages: he might here mention, that on the Croydon Line, which was laid on continuous bearings, a very disagreeable motion was always experienced. The difficulty of the drainage might be overcome by making the transomes level with the ground. His opinion on the questions under discussion was,—that longitudinal bearings were preferable to cross-sleepers,—that it was more advantageous to employ wood than stone,—and that repairs could be effected more speedily with rails of the T shape on chairs, than with bridge-rails fastened with bolts and nuts. A more important point was, that after a frost, or in wet weather, the ordinary old road laid with chairs was less slippery, and became sooner fit for traffic than a road laid with bridge-rails on longitudinal sleepers. With regard to the shape of the rail, his experience led him to believe, that with an equal weight of metal, the hollow bridge-rail did not wear so well as the double-T rail.

Mr. WYNDHAM HARDING also thought, that although stone blocks lasted longer than wooden sleepers, there were many reasons in favour of the latter, which more than counterbalanced the advantage of duration; and stone was gradually being replaced by wood. The permanent way of the Dublin and Drogheda Line, laid down by Sir John Macneill, was composed of a high bridge-rail of from 85 lbs. to 90 lbs., fastened down, without chairs, on cross-sleepers, which were placed, in accordance with mathematical calculations, at unequal distances, the rails being well straightened and accurately gauged, and the sleepers being cut with a machine to the right bevil. The road had now been down for some years, and he had never seen a line in better order; but it was only fair to add, that the traffic was small, the engines light, and the speed moderate. The objection of Sir John Macneill to longitudinal sleepers was their liability to turn on their axis; but this, Mr. Harding thought, might be remedied by keying. He had found

that the bridge-rail wore worse, with an equal weight of metal, than a rail of the T form, or a common contractor's rail.

Mr. STATHAM said the Chichester Line had been laid with a bridge-rail of 75 lbs. to the yard and with transverse sleepers, and the system had entirely failed; it might answer on the Drogheda Line where the traffic was light, but where it was of a heavy description, a continuous longitudinal bearing was decidedly the best. The Croydon rail was not a bridge-rail, but a common contractor's rail. Time and experience only could fully test Mr. Hawkshaw's plan, but it seemed to him to be a decided improvement. The proposal of fishing the double-headed rail might, probably, succeed; the turning of the double-headed rail was only adopted when one surface had been crushed, or was imperfectly manufactured. The contraction and expansion was less injurious with that form, than in the longitudinal system. The two systems were to be seen, side by side, on the Greenwich Line.

Mr. WHISHAW was satisfied, that elm would never answer for sleepers, as it had been generally found to decay in eighteen months. He thought, that kyanizing the timber was not of the slightest use; and that light rails would not answer in practice, was proved in the case of the Great Western Railway, where, as far as Slough, the rails of 45 lbs. had been very rapidly destroyed. The system of laying the permanent way which had been alluded to as being Sir John Macneill's, was originally suggested by Mr. Giles, who did not use chairs, but spiked down the rails to the fir sleepers; that plan was found not to answer, and the road was taken up.

Captain W. S. MOORSOM said the form of rail adopted by Mr. Giles was much too weak, and that was the main cause of its failure.

Mr. EATON HODGKINSON conceived, that there must always be a sinking of the rail, from the soft nature of the timber, and the inadequacy of the bearing surface, and that the cross-bolts would do but little towards the general support. Account should also be taken of the alterations of form induced by the heavy weights rolling upon the rails.

Major-General Sir C. W. PASLEY considered the bridge-rail superior to the T rail, as it dispensed with chairs, which he believed to have been, to some extent, the cause of all railway accidents. Now as no accident had occurred on the Great Western Railway, from an engine having gone off, on account of a displaced rail, those which had happened on that line could always be accounted for; whereas on other lines, the chairs were broken, and there were often no means of ascertaining the cause of the disaster. Of the lines on which chairs were used, the best were those made by Mr.

Cubitt and Mr. Hawkshaw, in which the number of transverse sleepers had been increased; but the great point, in his opinion, was to get rid of chairs altogether, and if, from the first, wood had been employed for bearings, cast-iron chairs would never have been introduced. He was decidedly in favour of longitudinal bearings, notwithstanding that transverse sleepers afforded superior facilities for drainage.

Mr. HAWKSHAW said, although the plan might not present such superiority as to induce its general adoption, or the discarding of other systems, yet it possessed certain advantages. A portion had been laid down on a line which had some of the heaviest traffic in the kingdom, and the joints were as perfect as they could be, unless the rails were welded together. The object was to obtain uniform deflection throughout the whole of the rails, including the joints, providing at the same time for the contraction and expansion. If the part referred to remained until the end of the summer, in its present state, he should be satisfied that it would succeed, and he should lay down more on the same system. He had laid down a road for some distance on Sir John Macneill's plan, and the expense of maintaining it was found to be double that of repairing the other. He did not think the Dublin and Drogheda Line was a fair test of the system, as that railway had only been open since 1845, and the traffic on it was very light. He considered Mr. Samuel's proposal of fishing the joint of the double-headed rail well worthy of adoption, but he did not concur in the remainder of his views.

May 15, 1849.

JOSHUA FIELD, President, in the Chair.

The discussion upon the Paper, No. 805, "Description of the Permanent Way of the Lancashire and Yorkshire Railway, &c.," by Mr. J. Hawkshaw, being renewed, was extended to such a length as to preclude the reading of any other communication.

May 22, 1849.

On this evening, a Conversazione was given by the President to the Members and a large number of visitors; on which occasion, an interesting collection of Models of Engineering Construction and specimens of Works of Art, was exhibited in the rooms of the Institution.

June 5, 1849.

JOSHUA FIELD, President, in the Chair.

The following Candidates were balloted for, and duly elected:—The Right Honourable the Earl of Rosse, as an Honorary Member; Albinus Martin, William Radford, Henry Robertson, and James Samuel, as Members; Charles Cammell, Joseph Aaron Joseph, and Robert Mudge Marchant, as Associates.

No. 802.—"Description of a Method of Rolling Bars for Suspension Bridges and other similar purposes."* By Thomas Howard, Assoc. Inst. C.E.

THE manufacture of flat bars of wrought iron for suspension bridges, having heads at the ends to receive the eye, or hole for the connecting pins, has hitherto been effected by welding the heads on to a parallel rolled bar, or, in some few instances, by hammering them to the required form. The process by welding is insecure and cannot be relied upon, more especially in large work; and the process by hammering is expensive, comparatively slow, and presents other disadvantages. The present process completely obviates these objections, as by it the bars are rolled at once into the requisite form. This is effected by first passing the shingle, or faggot, at a welding heat, longitudinally through grooved rollers, in the ordinary manner, and when only partly drawn down to the intended thickness, it is carried to rollers having bosses, or increased diameters at the place corresponding to the heads to be produced. It is passed to and fro through these rollers transversely, or across the breadth of the bar, and receiving a pressure only at these enlarged parts of the rollers, acquires the necessary increase of breadth at the heads; and it is then taken to plain finishing rollers and drawn out longitudinally in the usual manner, until of the required length and thickness. The heads are afterwards trimmed by machinery to the exact dimensions.

In testing bars welded with the utmost care, it was found, that reliance could not be placed on them, several giving way, on proving at various tensions, at the weld, or shut. The iron too, on each side of the weld, appeared to have become granulated, and deteriorated in strength, by receiving nearly a welding heat without sufficient subsequent working to restore it to the fibrous condition.

* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

The chains of the suspension bridge over the Danube at Pesth, designed and erected by Mr. William Tierney Clark, were constructed on this new system, at the King and Queen Iron Works, Rotherhithe. This bridge is the largest hitherto built on the suspension principle, and it is highly satisfactory to be enabled to state, that out of upwards of five thousand links, weighing from 4 cwt. to 6 cwt. each, not one showed any defect, or indication of derangement in the proving, which was done with great care and under close inspection. The bars were rolled from laid-up hammered slabs of scrap-iron. The test was 9 tons to the square inch of section, at which no permanent set was to be allowed, nor was any appreciable, either in the bars, or heads: the gauge being a plain 10-feet rod with steel points, and a steel radius rod over the heads. The elasticity, or temporary stretch, while under tension, was about $\frac{3}{16}$nds of an inch in 10 feet. The test was occasionally carried higher, for the sake of observation.

It may, perhaps, be interesting to state, that proving these bars and making the preliminary experiments disclosed the following facts:—that wrought iron is appreciably elastic at less than 1 ton to the inch, in a length of 10 feet;—that the best iron begins to indicate a permanent stretch, or set, at about, or a little over 10 tons to the inch, in a length of 10 feet;—that repeated testing does not appear to effect a change, or to impair the elasticity;—that this inherent elasticity is but little diminished by further considerable tensions, and after an apparent permanent set, or elongation, has been given to the bar;—that the permanent set does not go on increasing by a considerable lapse of time under the same strain;—and that on applying additional strains, each produces a set, or stretch, to a limited extent only, and so on, periodically, until the breaking point is arrived at, which may be taken at about 28 tons per inch, for good strong iron.

A singular confirmation of the insecurity of welds occurred in the erection of the main chains of the Pesth Bridge, during which operation a link of the hauling chain, or cable of 2-inch iron gave way at the shut, although it was a proved chain, made expressly for the purpose, by an eminent manufacturer. The fracture presented the appearance frequently observed in the breaking of chains, namely, a partial opening at the shut, and a break through the remainder exhibiting a granulated surface; whilst the disruption on the opposite side of the link was in fibrous iron. A further elucidation was presented by the giving way of the chain bridge at Yarmouth, the bars of which proved defective at the welds, at one of which the

derangement commenced, as described in Mr. James Walker's report, after the accident.

The chains for the bridge at Kieff in Russia, erecting by Mr. Vignoles, were manufactured on this new system; and the chains for lifting the Conway Tubes, as also those to be employed for the like purpose at the Britannia Bridge, over the Menai Straits, were made at Rotherhithe on this plan.

Mr. HOWARD exhibited a model of the bars used in forming the suspension chains of the Pesth Bridge, erected from the design of Mr. W. Tierney Clark. He had found no difficulty in bringing out the bars so accurately, that they were produced within half an inch of the necessary length, between the heads. Every bar was rolled within one-hundredth part of its required thickness, and when they were proved, not one out of the very large number was found defective; this was calculated to give Engineers great confidence in the soundness of the work they designed. The bars for the bridge at Kieff, now erecting under Mr. Vignoles, had been manufactured by Mr. Thorneycroft, under a licence from Mr. Howard.

Mr. FAREY said, this process was a great improvement on the system of welding on the heads, which must be a bad plan, for any bars that required strength, as the fibrous texture which had been acquired by rolling, was necessarily injured by the heat necessary for welding. If the heat was only slight, so as to do the least injury to the fibrous quality of the iron, the weld would probably be defective, and if a good welding heat was obtained, the fibrous quality was certain to be destroyed; so that he thought the plan of avoiding the process of welding was of great importance, and it had been effected in a manner equally simple and ingenious.

Mr. HOWARD, in answer to questions from the President, explained, that wrought-iron rollers 5 feet in length were used for the purpose of forming the heads, to effect which, the bar, when at one-half its finished thickness, was offered transversely to the rollers, the middle part of which did not touch the bar at all; it was then passed longitudinally through plain rollers without grooves, and brought to its proper thickness and elongation, arrangements having been previously made for its exactly reaching the required length. The bars made in that manner for the Pesth Bridge, weighed from 5 cwt. to 7 cwt. each, and were each finished at one heat.

In answer to a question from Mr. Gregory, Mr. Howard stated, that the machine used was not powerful enough to test any of the bars to the breaking strain; they were occasionally proved up to

15 tons or 16 tons, but never beyond that tension. They were all proved to the extent of 9 tons to the square inch, although the actual strain they were intended to sustain would not exceed 6 tons per inch. The whole of the Austrian and Hungarian armies had lately unexpectedly passed over the bridge, and had imposed a load from one end to the other equal to a strain of 7½ tons per inch on the chains, and though the structure was not completed, no injury was received by it.

Mr. CROKER said, that under Mr. W. Tierney Clark he had superintended great portions of the work at and for the Pesth Bridge. Before giving out the contract, many experiments were made on different qualities of iron, and that prepared by Mr. Howard's process was found to be the best. The desire to furnish so large a quantity of links at a comparatively low price, led to the adoption of Mr. Howard's ingenious method of rolling the bars, and it had proved most efficient. Each link, or bar, was made of the best scraps, faggoted; seven faggots, 1 inch in thickness, composed a pile 4 feet long; this was rolled to 6 feet, and was taken to the wrought-iron rollers with the bosses on them, which rolled the heads transversely, and the bar was then extended to the required length under plain longitudinal rollers, the whole process being completed at one heat, in about four minutes. After the bar was rolled, the eyes were bored, and it was then taken to a pair of shears, where the heads were pared round to the required shape. The bar was now subjected to a strain of 9 tons per square inch, by which the metal at the back of the hole was compressed. During the process of proving, a rod 10 feet long with steel points was used, to show the extension of the metal. The condition in the contract was, that every bar which showed any permanent set, when the strain was taken off, should be rejected, and with a magnifying glass, no difference could be detected in any one of them; the eyes were all also examined carefully, by means of a radius rod from the throat of the bar. As soon as the bars were proved, they were placed together in sets of ten and eleven alternately, and the eyes were bored through altogether, under a powerful boring-machine, to a diameter of exactly 4½ inches.

Each chain was composed of sets of links of ten and eleven bars alternately; the dimension of each bar was 12 feet, from centre to centre of the bolt-holes, varying in thickness from 1·25 inch at the summit, to 1·08 inch at the apex, and all of them were 10½ inches wide. There were four chains, two on each side of the bridge, having a total sectional area at the summit, of 520 square inches, and at the apex, of 487 square inches. The span of the centre opening

was 665 feet, and those of the two side openings were 297 feet each, and the versed sine, or deflection of the chain, was 47 feet 6 inches. The length of chain in the tunnel was 125 feet, and the platform was 45 feet wide over all. The coupling bolt was 4½ inches in diameter, with a square thread of ¼ inch pitch cut in each end for receiving a cast-iron nut. The dimensions of the links were definitely fixed, by experiment. The head was 7 inches deep behind the bolt, and 5½ inches on each side, which gave ½ an inch more of section in the metal of the head than in the body. It was doubtful which part would break first. One link, which was broken by a torsive strain, parted at 11 inches below the head. All the dimensions were arrived at by actual experiment, as well as by calculation.

The first experiments were made with a bolt 3½ inches in diameter, but when a load of 9 tons to the square inch of section of the bar, was laid on, the metal of the head of the link immediately behind the pin was found to be very much compressed; the object, therefore, of having a pin so much larger than was actually necessary, was to obviate that injurious tendency. It resulted also from the experiments, that more strength could be obtained in the head by enlarging the bolt. The proof load used was 9 tons per square inch, but this was often increased to 13 tons, in order to test the quality of the material used. The bolt-holes were ¼th of an inch oval in front of the bolt, to admit of the chain being put together with facility.

Some links which had been hammered were found not so regular in the proof, as those rolled in the manner described, but not one single bar was rejected, out of upwards of five thousand supplied by Messrs. Howard and Ravenhill. On the retreat of the Hungarians across the river into Pesth, when they were immediately followed by the Austrians, seventy thousand men and three hundred and fifty pieces of artillery passed over the bridge in one day.

Mr. C. H. Gregory remarked, that in the absence of a test up to the point of fracture, a larger area of section at the eye, beyond that shown by Mr. Howard, would have appeared desirable, on account of the disadvantageous way in which the pressure was applied; the tendency being to tear the iron, by giving a greater strain at the inner part of the eye, than at the outer part. For that reason, he conceived, that the head was not so strong as the other part of the bar.

Mr. Croker said, that in the bars for the Pesth Bridge the pin was made three times as strong as was necessary for its own work, in order to avoid the compression of the metal at the back of the eye, which was inevitable in using a smaller pin. When the bridge was completed, there would be six rows of trussing, 10 feet deep,

running longitudinally, to prevent oscillation, and undulation. When the army passed over, none of those had been erected, and the platform was only temporary, yet there was scarcely any prejudicial motion.

Mr. FIELD,—President—in answer to questions from Members, said, that a series of experiments had been made, before the Menai Bridge was built, the object of which was to ascertain the best dimensions of the pin, the head, and the body of the link. Those experiments were recorded in the account of the Menai Bridge published by Mr. Provis.*

Mr. HOCKING said, he was present at the making of the greater portion of the links for the Hungerford Suspension Bridge, which were manufactured at the Copper-house Foundry, Hayle, Cornwall, and having seen the majority of them tested, he could vouch for none of the welds having failed. Out of about twenty bars which were purposely broken in a machine, under a strain of about 24 tons per inch, only one gave way at the weld. The heads were all welded on to the bars at about 18 inches below the eyes; the bars were rolled 7 inches wide by 1 inch in thickness, and an additional thickness was given near the summit of the piers. Some of the eye-plates were rolled and some were hammered, yet little difference was found in their strength. Many experiments were tried, to ascertain the best size and shape for the eyes, and the result arrived at induced the adoption of dimensions, which gave rather more iron round the eyes, than the proportions shown in the model of the links of the Pesth Bridge. The pins were 4¼ inches in diameter, which was much larger in proportion than was shown in the model. Mr. Hocking was of opinion, that the size of the pins was a point of great importance. The two eyes of each link were drilled simultaneously under a machine constructed for the purpose, which only admitted one link at a time; extreme precision, in the distance between the centres, was, however, obtained.

In answer to a remark, that some of the eyes on the Hungerford Bridge were not accurately drilled, as they did not fit the pins closely, but might be shaken by the hand, Mr. Hocking observed, that no complaint of that kind had been made of them; that he was not cognizant of the fact, and should like to know by what means it was ascertained, that the links were loose on the pins. One of Mr. Brunel's assistants was present during the whole process, and he tested each bar as it was finished. As to the remark, that

* *Vide* "An Historical and Descriptive Account of the Suspension Bridge constructed over the Menai Strait," &c. By W. A. Provis. London, 1828.

changes of temperature in the links would prevent their being accurately drilled singly at both ends at the same time, he observed, that there was no difficulty experienced on that score, with the machine used on the occasion to which he had referred. In the heads which were purposely strained up to the breaking point, three fractures usually occurred, one at the back of the eye, opening at the periphery of the semicircular head, and one on each side, opening at the inner diameter of the eye.

Mr. Hocking was not aware of the comparative expense of the two modes of manufacture.

Mr. CROKER, in answer to questions from Mr. Wyndham Harding, said, that by rubbing the head with chalk, before the strain was put on in proving the links, it could be seen how the pressure affected the head; the chalk being thrown off in small flakes, as the pressure extended. By making the bearing surface larger, at the back of the eye, the crushing effect of the pin upon the metal was counteracted.

Mr. SLATE was of opinion, that the bars which had been hitherto made for suspension bridges, were generally too thin in proportion to their depth; and that the compression of the pin entirely destroying the elasticity of the iron, close to the back, there was then nothing left, except the strength of the outer rim, to sustain the weight of the bridge. He considered this to be a point which, unless closely watched, would be likely to escape observation. His experiments convinced him, that the pins were generally too small, in proportion to the size of the bars. He found, that when a strain of 9 tons per inch was arrived at, the pins were compressed much more than the iron of the bar; he had, therefore, substituted steel pins of a mild temper, and he found, that they were not compressed at all. He thought the idea, that iron, once compressed, would resist further compression, was quite erroneous. If the pin was pressed strongly against the inside of the eye, it destroyed the elasticity of the iron, immediately in contact with it, and by the extent of the compression virtually increased the diameter of the pin; the elastic metal still remaining around the eye being sufficient to bear the weight.

There were many interesting facts still to be elicited, with respect to the elasticity of cast and wrought iron, and the experiments he had made induced Mr. Slate to arrive at conclusions materially differing from those ordinarily received, and which he would soon lay before the Institution.

Mr. HOWARD showed, that the effect of the strain of the pin on the head, extended on either side, from the diameter of the eye, in

a peculiar curve to the back, and increased in proportion to the strain applied. The metal within this curve was compressed, in proportion to the distance from the eye. In practice, he had advantageously used this to resist any change of length in the chain, and the eyes were cut away at the inner side to give them the oval form necessary for the convenience of putting together the sets of links; small pins had invariably been found more injurious than those of larger diameter. The compressed metal, of the interior of the eye, actually represented a collar of steel, which prevented a further amount of compression: this was very beneficial, as his experience showed, that wrought iron was more readily compressed than extended.

His opinion was, that up to the present time, the bars of suspension bridges had not been made with a proper proportion between the bearing surface on the pin and the sectional area of the bar, below the head; all the bars were, generally, stronger than the head.

Mr. VIGNOLES fully concurred in the propriety of increasing the diameter of the pin. In the bridge at Kieff, in Russia, now building under his direction, the chain of which had an area of 330 square inches and a span of 440 feet, between the points of suspension, he had adopted a link very similar to the one exhibited, only enlarging the sectional area of the head, and making the pin 5 inches in diameter instead of 4¼ inches, and he was inclined to think it would have been improved by being made even still larger. The result of a series of experiments made at Messrs. Fox, Henderson & Co.'s works and of other subsequent trials, induced a conviction in his mind, that the form of the head might be still further modified, so as to assume more the shape of the link of a common chain than that which was generally given to it; for the head, as now made, was generally weaker than the main body of the chain. So strong was his feeling on this point that, before he proceeded with the erection of other bridges, for which he had made the designs, he should make other and more complete experiments to satisfy himself of the best form of disposing the iron in the link. At present, he was inclined to receive a modification of that form, now exhibited, as the best, only extending the principle by increasing the diameter of the pin, so as to augment the bearing surface at the back, and cutting away the inside of the eye in a triangular form. He thought Mr. Howard's method of manufacturing was not only ingenious, but a manifest improvement upon the ordinary mode of welding on the ends, as although the greatest care and skill might be and was exercised, yet there was always a risk of an unsound weld occurring.

Mr. BRUNEL said, that fifteen years ago, he made a series of experiments as to the best form of links for suspension bridges, and he arrived at the same general conclusions as Mr. Vignoles, with respect to the form of the head and the diameter of the pin; he thought, that anything less than two-thirds of the breadth of the bar for the diameter of the pin was too small; that proportion would give a pin larger than was shown on the model of the link of the Pesth Bridge. With a pin of which the diameter was two-thirds the breadth of the bar, and a moderate increase of strength of metal round the eye, he believed the strength of the head would be equal to that of the body of the bar. He was disposed to think, with Mr. Vignoles, that the strength of the eye would be increased, by cutting out a triangular piece at the inside. No part of the link must be strengthened so as to destroy equality of elasticity. He thought, that scarcely sufficient attention had been given to the proportions of the bar and the heads, or to the general proportions, which should be calculated, so that the greatest load should not produce a pressure of above 5 tons, or 6 tons per square inch; and that the strain should be equally extended over the whole structure. The method of rolling the links was, no doubt, a great improvement, still he thought that, with moderate care, the welded links were equally strong, and he disagreed with Mr. Farey's opinion as to the injury to the metal in welding, for in his experiments on welded links, Mr. Brunel had found, that the welded portion of ironwork was fully as strong as the other parts. He must also contradict the assertion as to the ill fitting of the links of Hungerford Bridge; there might be an appearance of looseness, because he had adopted the plan of making the holes oval, so that the pins might be more easily passed through; but he was convinced, that there was no perceptible difference in the length of the links, as when they were erected there certainly was not a difference of one-fiftieth part of an inch in the length of any two of them. He had never seen, nor had he received any report of the rattling of the links on the pins.

June 12, 1849.

JOSHUA FIELD, President, in the Chair.

No. 811.—"On the Construction of a Collar Roof, with arched trusses of bent timber, at East Horsley Park." By the Right Honourable the Earl of Lovelace, Assoc. Inst. C.E.

THE roof of this hall, which covers a space of 56 feet by 24 feet, is sustained and tied by four arched trusses, springing from stone corbels placed 8 feet below the wall-plate.

The ribs, instead of being constructed in the usual method by carpentry, are formed of separate, parallel, longitudinal timbers, bent to the requisite curve by steam heat.

The arch (Plate 8) consists of eight different battens, each 20 feet in length, and 3 inches in thickness; the breadth, as is shown by the section, is, for the pair forming the intrados, 4 inches, the next 6 inches, the next 8 inches, and for the upper, or external pair, 11½ inches. The roll was worked upon the face of the lower member, and the mouldings on the faces of the others, before they were subjected to the action of the steam.

The steaming operation was effected, by placing as many of the timbers as could be conveniently stowed at one time, within a long stout air-tight plank-chest, into the side of which was inserted the pipe of a temporary boiler: after four, or five hours' exposure to the steam, each piece was successively brought out and bent round a gauge formed by strong posts firmly fixed in the ground: when cold, the timbers so treated were removed, and showed no tendency to lose the curve they had acquired. Previous to their being hoisted up to their eventual position in the building, each set of four was firmly pressed and lashed together: the arc thus formed was still further controlled by a long iron rod connecting its extremities as a bow-string, and which remained until the corresponding arc was duly placed on the opposite corbel, united with it at the apex, and closed by the superposition of the principals and collar-beam; and when the whole had come to its proper bearing, it was secured with bolts and nuts.

The small mouldings which surround the tracery in the spandrils, and on each side of the king-post, have been obtained by the same means; they consist of three distinct members: an inner roll, a cavetto, and an outer roll; of these, the latter is so arranged as to form a continuous border round each figure, the upper portion of one

curved circumference becoming the lower one in the next, by its intersection with the corresponding head, as shown in the lower par of the figure on the left hand.

The tracery is cut out of tub-stave oak, formed of half-inch thicknesses glued together, in such a way that the longitudinal fibres of one thickness are crossed at right angles by those of the other. This renders the execution of the cutting more easy, while it increases the strength of the material.

The under surfaces of the rafters are slightly moulded, and the re-entering angle, which they make with the ceiling, is filled with an additional moulding. The ceiling itself is formed by half-inch diagonal boarding. As the slate battens traverse this again in a horizontal direction, the roof is strongly braced and secured against the action of the wind: each alternate board of the ceiling has been stained of a darker colour than its neighbour, and an agreeable effect of perspective has thus been obtained, without interfering too much with the tracery in the vertical planes.

The notion of this roof was first suggested by the perusal of the work on carpentry by Colonel Emy,* by whom it was successfully employed to cover areas of large span, such as cavalry barracks, where open space was required for manœuvring, free from the interruption of supports. Emy, however, used only a flat segment of a very large circle, the curve being so inconsiderable, that the battens were easily brought to it without the aid of steam. That at Marac is 60 feet across, at Libourne is one 68 feet; and Colonel Emy was confident, that a span of even 300 feet might be embraced by a roof so carried. The number of edifices which have been erected of late years, in the Pointed and Tudor styles, renders it surprising, that the resources presented by this method should not have been brought into play.

In setting out the arches now under consideration, the object has been to pass a curve through three given points, so that the planes of the wall and the principal rafter should form tangents to it, and that it should also intersect the opposite curve immediately under the king-post; this arrangement will be found to satisfy the conditions of solidity. The arch is bolted to the principal rafters, in such a way as to prevent them from spreading; an arch of wood, (different from one of masonry,) presenting very considerable resistance to the outward drift of the principals.

In the present instance, the arch advantageously replaces an effect usually sought for in roofs of this figure, by the hammer-beam and

* "Traité sur la Charpenterie," par A. R. Emy, Colonel du Génie. Paris, 1830.

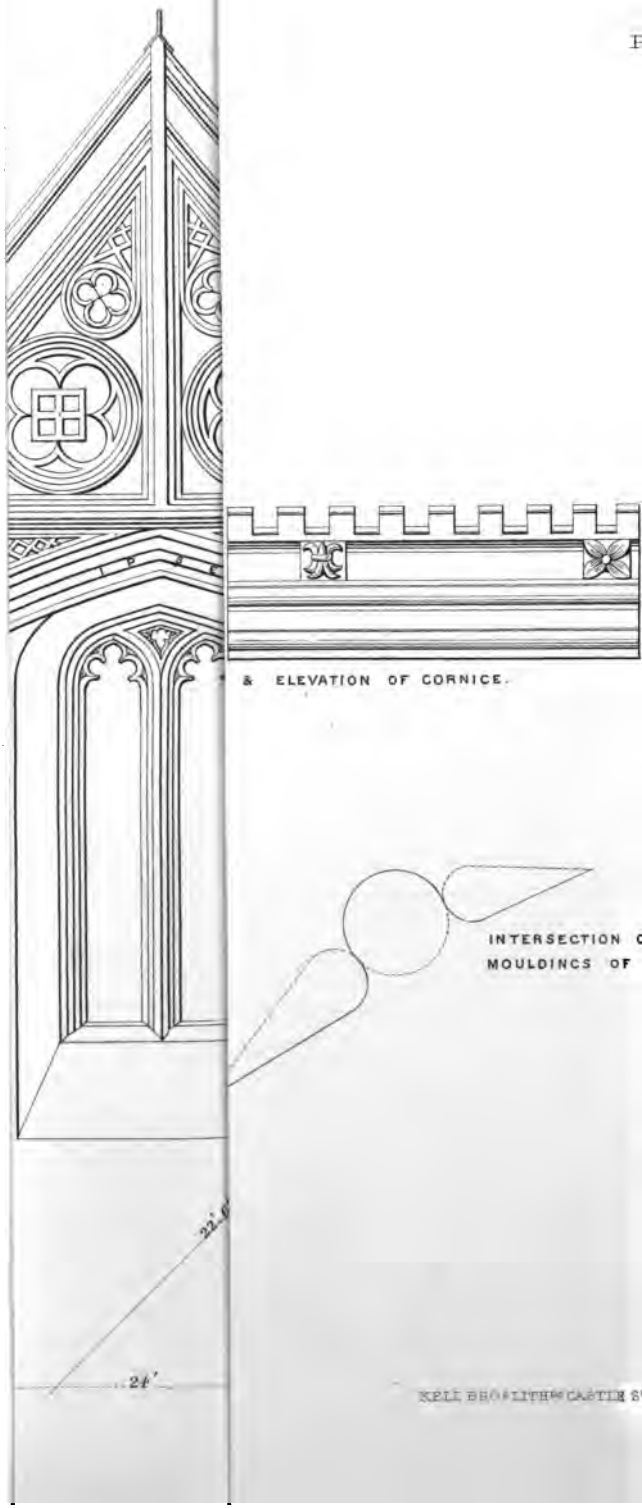
pendant-post, or wall-piece, the timber arch intercepting and conducting the outward thrust away from the foot of the rafters and the wall-plate, where it would have most power, and resolving it down inside the walls to such a depth, that were they thinner, or without buttresses, no strain could there be exercised upon them.

The ancient roofs erected in the fifteenth and sixteenth centuries are very instructive in their way, although the different quality of the materials of which they were composed, required for the most part, a management other than that to which modern builders resort. The style of the architecture required a certain steepness, and probably also, the imperfect porous covering substances, when copper, or lead were not used, rendered it desirable, that the rain should be carried off as rapidly as possible. The elevation, therefore, generally exceeded forty-five degrees: this great angle will at once account both for the character of their construction and of their decoration; indeed, the latter was made wholly dependent on the former, a principle which is sometimes lost sight of in modern structures.

The woods, also, had much influence; where rigid pine is now used, our forefathers employed oak, or chesnut: either of them cut into rafters, such as are common at present, would have been liable to cast, and to exhibit a distorted appearance from below. This was obviated by a more frequent use of purlins, and by the introduction of diagonal bracing; and as the latter traversed the under surfaces of the rafters, it was made the vehicle of an expressive decoration; and while they kept each individual rafter in its proper place, they contributed in the aggregate to stiffen the whole structure against the winds, to which its lofty elevation exposed it. The artificers of those times had a tougher, as we have now a more rigid material, whose respective qualities in each case suggest their own appropriate treatment.

The Paper is illustrated by a diagram, from which Plate 8 is compiled.

The Earl of Lovelace said he was unable to state the difference between the cost of construction described in his Paper, and the ordinary method of carpentry, because in the first construction of the kind the methods employed might not be so perfect as could be desired, and also because the men were not solely engaged upon it, for any consecutive period, as the timbers could only be operated upon when the steam had sufficiently softened them. He submitted, that the labour must be obviously less than for carpentry, and that a roof so constructed must possess greater strength, whilst it did not



& ELEVATION OF CORNICE.

INTERSECTION OF OUTER MOULDINGS OF TRACERY.

KELL BROS LITH^{rs} CASTLE S^T HOLBORN.

push against the walls like an ordinary span-roof. The subject was interesting to Engineers, who were often called upon to construct roofs for buildings of large size, to which iron, notwithstanding its great advantage, was not always applicable, when more than an ordinary degree of ornament was required. The width of the hall, for which the roof had been constructed, was 24 feet, and the radius of the shortest curve of the main arch was 7 feet.

In answer to questions from Captain Moorsom, the Earl of Lovelace said it must be clear, that great advantage would arise from taking off the strain from the top of the walls and conveying it some distance down them, as was done by the hammer-beam in the old roof, only he thought it was better done on this system. The whole of this roof was so bolted together, that any action of wind upon it would be felt throughout the whole structure; he believed that was a principle much insisted on in the roofs of the middle ages. He did not pretend that the system was entirely new, for he was aware that it had been used in the construction of railway viaducts and bridges of large span; but the curve given to those arches was so slight, that it had not been necessary to employ steam for bending the deals. Philibert de l'Orme had also, about three centuries ago, described roofs, of which the principals were built with short planks cut to the required shape, and pinned together vertically. That method could not have been used for this roof, on account of the ornaments, as the outer planks would have been partly cut away in working the mouldings, and the whole strain would have been thrown upon one, or two of the inner planks.

Mr. Brunel could not conceive how the advantage of such a construction could be at all questioned; there was so much real utility in it, that the Institution must be indebted to Lord Lovelace for directing attention to so obvious an improvement in roofs which, in general, were expensive and troublesome. Mr. Brunel thought the roof he had constructed over the Bristol Station of the Great Western Railway was an improvement on the ordinary system, but he preferred this system to that which he had adopted. The roof he alluded to had a span of 74 feet; it was formed by framing timber together, plating them on both sides with iron, and disguising the construction by ornaments applied to the timbers, instead of working them in the timber, as had been done by Lord Lovelace. The style of architecture to which it had been applied, particularly demanded bold mouldings, which could, by this system, be worked on the edges of the bent timber, in the direction of the grain, and the strength of the wood was never impaired. In fact, he had seldom seen so simple and useful a roof, possessing such an

amount of stiffness, and at the same time avoiding all thrust upon the walls.

Mr. WALKER agreed, that there might not be a great degree of novelty in the roof, but there was much real utility in it, and much ingenuity had been displayed by the Earl of Lovelace, in the design and the construction. Mr. Walker thought the great advantage consisted in enabling roofs of such a peculiar form to be constructed out of ordinary deals, instead of cutting away a quantity of timber wastefully, and he thought it would have been very difficult to have found timber from which such short curves, as 7 feet radius, could have been cut. Perhaps, however, the most interesting result of all, was to find the noble Lord occupying himself practically with the details of construction, and then coming to the Institution to impart the information he had acquired, and to court discussion upon his works.

Mr. VIGNOLES corroborated the preceding remarks, and thought that one of the chief merits consisted in getting rid of the hammer-beams, and in preventing the thrust coming upon the top of the wall; he thought the principle of built-up and bent timber beams was capable of extension to ship-building; it was already used in mast-making, and there was not, in his opinion, any valid reason why this system should not be adopted, when it was considered what great pains were often taken to procure knees of timber of a particular shape, and which could, by the above means, be avoided. Timbers large enough for the roof of Westminster Abbey, and of the requisite shape, might in that way be obtained. Indeed, he thought the principle applicable to roof, ship, or bridge building.

The DEAN of WESTMINSTER remarked, that at Amiens there was a fine instance of construction of a roof with hammer-beams, which dated from the thirteenth century. He thought there was little chance of the proposed mode being applied to Westminster Abbey, as on an inspection made by Lord Lovelace and himself, a short time ago, there was not a foot of the timber roof which was not as good as when the roof was first erected. In answer to a question from Mr. Beardmore, the Dean of Westminster stated, that the timber of the Abbey roof was supposed to be built of chesnut, but it had not been examined microscopically.

No. 812.—"Statement of Observations, made during the running of the Ordinary Trains, on the Inclined Planes of the Waterford and Kilkenny Railway, between the months of August 1848 and January 1849." By Captain William Scarth Moorsom, M. Inst. C.E.

THE following observations were made, with the view of giving practical facts, in reference to velocities of railway carriages, on the Irish, or intermediate gauge of 5 feet 3 inches. Numerous observations are recorded of like character on the narrow gauge of 4 feet 8½ inches, and a few have been recorded on the broad gauge of 7 feet. Some of the latter were brought under the notice of the Institution, at the close of the session of 1848,* and it appeared to the compiler of the present Paper, that these latter observations did not give sufficient data for any sound deduction, owing chiefly to the short space within which the records were made. Several Members of the Institution imagined, that the gauge of the carriages might materially influence the results of terminal, as compared with initial, velocity, and it seemed, therefore, desirable, that the Institution should be supplied with a new series, in dealing with which no peculiar bias as to gauge need interfere.

In considering these trials, it must be remembered, that they are the ordinary experience of every-day work, between August 1848 and January 1849; so that various states of the rail and various kinds of weather were encountered; particular trials may, therefore, be expected to differ from each other more than would probably be the case, had the same loads been started with the same speeds, during the same weather. But if their value, as abstract experiments, be subject to question in this respect, their practical bearing upon the working of ordinary trains is unquestionable.

It appears from the Abstract, (Appendix, Table I., p. 289,) that on the more curved plane, the initial velocities between 20 miles per hour and 30 miles per hour, become terminal velocities, at the end of about 1¼ mile, varying from 24 miles per hour to 28 miles per hour, while, on the straighter plane, similar initial velocities become terminal, in a range of velocity from 29 miles per hour to 36 miles per hour, in the same distance. Again, on the more curved plane, the initial velocities, between 30 miles per hour and 40 miles per hour, terminated in a range of velocity from 29¼ miles per hour to 31½ miles per hour, while, on the straighter plane, the correspond-

* *Vide* Minutes of Proceedings Inst. C.E., vol. vii., pp. 292-326.

ing initial velocities terminated in a range of velocity, from 30¾ miles per hour to 33½ miles per hour. The initial velocities, over 40 miles per hour, were noted only on the more curved plane, and resulted in terminal velocities of between 30 miles per hour and 31 miles per hour. There does not appear to be any constant proportion between the terminal velocity and the load in motion.

The lowest terminal velocities have not been arrived at, on each of the planes, with the heaviest load on each: and the ranges of such terminal velocities do not vary constantly on the loads, but on the contrary, are irregular as regards the proportion of load, and have more direct reference to the initial velocity.

It appears to the conductor of these trials, that any deduction must be fallacious, which assumes, that the atmospheric resistance on railways is less than that which has been received by Engineers, during the last ten years. Such deductions, if based on experiments of high velocities, exceeding 50 miles per hour, on inclined planes of less than 2 miles in length, have, doubtless, their fallacy disguised, by the fact, that the momentum of a train, under such circumstances, is so great, compared with the elementary fraction of resistance tending to counteract it, that the distance traversed disappears, before the train has come to its 'bearings,' which 'bearings' are simply the equipoise established between the atmospheric resistance, with rolling friction in its aid, acting in one direction, against the impulsive motion of gravity, acting in the contrary direction.

The Paper is illustrated by diagrams, showing the frontage of the engines and carriages employed in the experiments.

APPENDIX.

TABLE I.—ABSTRACT of OBSERVATIONS on the VELOCITIES of TRAINS upon the INCLINED PLANES of the WATERFORD and KILKENNY RAILWAY, during 80 Trials.

THOMASTOWN INCLINE.						BENNETTSBRIDGE INCLINE.				
No. of Observations.	Load in Tons.	Miles per Hour. Initial Velocity.	Miles per Hour. Terminal Velocity.	Difference, in Miles.		No. of Observations.	Load in Tons.	Miles per Hour. Initial Velocity.	Miles per Hour. Terminal Velocity.	Difference, in Miles.
					CLASS 1.					
1	35⅜	24·3	26·5	2·2	Speed 20 to 25 Miles per hour.	4	54½ to 60½	23·5	30·4	6·9
						1	83⅓	27·0	36·3	9·3
7	32½ to 44	28·9	27·6	— 1·3	CLASS 2.	4	32 to 44⅓	29·3	29·5	·2
4	46⅔ to 59	29·3	28·0	— 1·3	Speed 25 to 30 Miles per hour.	3	50 to 54⅔	28·9	31·5	2·6
1	61½	25·5	24·3	— 1·2		5	61½ to 69½	27·7	32·8	5·1
2	78 to 94½	26·8	26·1	— ·7		1	79	27·8	30·8	3·0
9	32½ to 40¾	33·0	29·7	— 3·3	CLASS 3.	14	32 to 42¾	32·1	31·8	— ·3
6	46½ to 50½	33·1	30·3	— 2·8	Speed 30 to 35 Miles per hour.	6	45¾ to 57¼	31·7	33·5	1·8
						2	64⅔ to 65	32·8	30·8	— 2·0
3	32½ to 42¾	37·5	31·3	— 6·2	CLASS 4.					
2	45½ to 57	37·5	30·8	— 6·7	Speed 35 to 40 Miles per hour.	2	32½ to 32½	35·7	30·8	— 4·9
1	61½	35·2	30·8	— 4·4						
					CLASS 5.					
2	32 to 35½	43·2	31·7	—11·5	Speed 40 to 45 Miles per hour.					
38						42				

The weights of Engines and Carriages were:—

	Tons.	cwts.	qrs.
Engine, with Tender on the same frame . .	22	0	0
Carriage (average of Classes)	4	18	0
Waggon (empty)	3	6	0

TABLE II.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
CLASS 1.—Speed at the Top of the Incline, from 20 Miles to 25 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.									Remarks.	
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.	Pass. Carriages.	Waggons.
				Tons. cwts. qrs.											
1	T	21 Aug. 1848	3	35 14 2	24·3	27·8	26·5	26·5	27·0	26·5	27·8	24·3	26·5	2	1
2	B	12 Sept. ,,	2	54 5 2	24·3	31·1	27·8	26·5	26·5	32·4	31·7	30·8	29·2	2	3
3	B	19 ,, ,,	3	57 8 2	24·5	27·8	27·8	29·2	29·2	29·2	30·8	34·1	30·8	2	4
4	B	21 Oct. ,,	2	60 3 0	20·7	25·7	23·5	24·3	25·2	24·3	29·2	29·2	30·8	2	4
5	B	28 ,, ,,	3	60 7 2	24·5	27·8	27·8	29·5	29·2	29·2	29·5	36·3	30·8	2	5
		Average Initial Velocity			23·5								30·4	Average Terminal Velocity.	
6	B	2 Nov. 1848	2	83 4 1	27·0	27·8	30·8	30·8	34·1	30·8	32·4	34·1	36·3	2	6

TABLE III.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
CLASS 2.—Speed at the Top of the Incline, from 25 Miles to 30 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.									Remarks.
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.	
				Tons. cwts. qrs.										Pass. Carriages. Waggons.
1	T	25 Aug. 1848	2	32 3 2	28·8	29·2	27·8	26·5	23·6	27·3	23·6	22·7	21·2	2 .
2	T	18 Sept. ,,	2	32 4 2	29·2	27·8	29·5	29·5	30·8	30·8	30·8	30·8	30·8	2 .
3	T	29 Oct. ,,	2	32 8 2	28·2	29·5	26·5	25·2	26·5	25·2	25·2	24·3	28·1	2 .
4	T	18 Jan. 1849	1	37 8 0	29·2	30·8	32·4	30·8	30·8	30·8	32·4	30·8	30·8	3 .
5	T	16 Sept. 1848	3	39 2 3	29·4	29·2	30·8	29·5	27·8	27·8	27·8	26·5	26·5	2 2
6	T	22 ,, ,,	3	41 9 3	28·2	29·2	29·2	34·1	30·8	29·2	27·8	27·8	29·2	2 2
7	T	21 Oct. ,,	2	43 19 3	29·4	29·2	30·8	29·5	27·8	27·8	27·8	26·5	26·5	2 3
		Average Initial Velocity			28·9								27·6	Average Terminal Velocity.
8	B	2 Sept. 1848	3	32 0 0	29·4	27·8	29·2	27·8	27·8	26·5	27·8	26·5	26·5	2 .
9	B	29 Oct. ,,	2	32 3 2	29·2	30·8	29·2	30·8	29·2	29·2	29·2	30·8	30·8	2 .
10	B	5 ,, ,,	..	32 8 2	29·2	29·2	29·2	32·4	27·8	27·8	29·2	27·8	26·5	2 .
11	B	22 Sept. ,,	3	44 6 2	29·4	33·1	30·8	31·1	32·4	32·4	30·8	32·4	34·1	2 2
		Average Initial Velocity			29·3								29·5	Average Terminal Velocity.
12	T	19 Sept. 1848	3	46 14 3	29·4	29·2	30·8	29·5	27·8	27·8	27·8	26·5	26·5	2 3
13	T	20 Oct. ,,	2	50 12 0	29·4	27·8	26·5	29·2	29·2	29·2	29·2	30·8	30·8	2 2
14	T	26 Aug. ,,	3	57 0 0	29·4	29·5	27·8	28·1	27·8	27·8	27·8	30·8	29·5	2 5
15	T	3 Oct. ,,	2	59 1 0	29·2	29·2	27·8	26·5	25·2	27·8	27·8	26·5	25·2	2 { 7 and 1 Horse box.
		Average Initial Velocity			29·3								28·0	Average Terminal Velocity.
16	B	15 Jan. 1849	..	50 2 3	28·2	27·8	28·1	28·6	27·8	27·8	29·2	29·5	29·5	3 3
17	B	12 Aug. 1848	3	51 3 1	29·2	31·1	26·5	27·8	27·8	32·4	27·8	30·8	31·1	3 2
18	B	24 ,, ,,	3	54 15 0	29·4	33·1	30·8	33·6	34·1	32·4	30·8	34·7	34·1	2 4
		Average Initial Velocity			28·9								31·5	Average Terminal Velocity.

TABLE IV.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
CLASS 2.—Speed at the Top of the Incline, from 25 Miles to 30 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.								Remarks.	
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.	
				Tons. cwts. qrs.									Pass. Carriages.	Waggons.
19	T	24 Aug. 1848	3	61 10 0	25·5	21·9	22·7	21·9	23·5	22·7	22·7	23·5	24·3	2	4
20	B	19 Oct. ,,	2	61 7 2	26·2	27·8	27·8	29·5	29·2	29·2	29·2	32·4	30·8	2	4
21	B	15 Sept. ,,	3	61 9 1	27·8	25·7	31·1	27·8	31·1	32·5	30·8	31·7	33·1	3	3
22	B	3 Oct. ,,	2	62 16 2	29·2	27·8	29·2	26·5	25·2	25·2	26·5	27·8	27·8	2	4
23	B	26 ,, ,,	3	64 3 0	27·8	29·2	29·2	29·2	32·4	32·4	32·4	36·3	36·3	2	5
24	B	18 Sept. ,,	3	69 3 1	27·8	29·2	29·2	29·2	32·4	32·4	32·4	36·3	36·3	2	5
		Average Initial Velocity			27·7								32·8	Average Terminal Velocity.	
25	T	23 Aug. 1848	2	78 1 0	27·2	29·2	29·2	29·5	34·7	30·8	27·8	23·5	23·6	2	7
														Summed up in Abstract with No. 27.	
26	B	4 Nov. ,,	2	78 17 0	27·8	24·8	26·5	26·5	29·2	26·5	29·2	29·5	30·8	2	7
27	T	22 Aug. ,,	2	94 4 2	26·5	27·8	26·5	27·8	26·5	27·8	29·5	22·0	28·6	2	11

TABLE V.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
CLASS 3.—Speed at the Top of the Incline, from 30 Miles to 35 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.									Remarks.	
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.		
				Tons. cwts. qrs.										Pass. Carriages.	Waggons.
1	T	28 Sept. 1848	3	32 10 2	30·4	30·8	29·2	30·8	32·4	30·8	29·2	32·4	32·4	2	.
2	T	12 ,, ,,	2	32 14 2	34·1	32·4	27·8	34·7	30·8	32·4	30·8	27·8	31·1	2	.
3	T	25 ,, ,,	2	35 2 3	34·1	30·8	29·2	30·8	27·8	27·8	30·8	27·8	29·2	2	1
4	T	19 Oct. ,,	2	35 4 0	34·1	38·6	33·1	38·6	32·4	34·7	34·1	32·4	32·4	2	1
5	T	26 Sept. ,,	2	35 16 0	32·8	30·8	29·2	30·8	32·4	30·8	30·8	27·8	26·5	2	1
6	T	2 ,, ,,	2	35 17 0	32·8	31·1	33·4	30·8	29·2	30·8	29·5	27·8	29·2	2	1
7	T	22 Aug. ,,	2	38 14 1	32·3	34·1	38·6	32·1	32·4	32·4	29·5	22·9	24·8	2	2
8	T	14 Sept. ,,	3	38 18 0	32·8	30·8	32·4	34·1	34·1	36·3	29·2	34·1	30·8	2	2
9	T	20 ,, ,,	3	40 15 2	34·1	34·1	30·8	29·5	34·1	30·8	32·4	26·5	30·8	2	2
		Average Initial Velocity			33·0								29·7	Average Terminal Velocity.	
10	B	16 Aug. 1848	3	31 18 2	32·8	32·4	29·5	28·1	29·5	25·7	24·9	26·5	26·5	2	.
11	B	19 ,, ,,	3	31 18 2	31·6	27·8	27·8	29·5	25·2	26·5	27·8	24·9	26·5	2	.
12	B	25 ,, ,,	2	31 18 2	34·5	33·1	34·1	34·1	34·7	32·4	34·1	34·1	34·1	2	.
13	B	23 Sept. ,,	3	32 3 1	32·1	33·4	34·1	32·4	32·4	34·7	32·4	34·1	34·1	2	.
14	B	27 ,, ,,	2	32 3 2	32·8	30·8	34·1	30·8	34·1	32·4	30·8	34·1	30·8	2	.
15	B	26 Aug. ,,	2	32 4 0	31·1	38·6	33·4	34·1	32·4	34·1	36·3	34·7	40·9	2	.
16	B	1 Sept. ,,	3	32 6 0	31·6	26·5	27·8	27·8	25·7	24·3	24·3	24·3	25·7	2	.
17	B	25 ,, ,,	2	35 9 0	32·8	32·4	34·1	32·1	34·1	32·4	34·1	34·1	34·1	2	1
18	B	1 Nov. ,,	3	36 13 1	30·4	27·8	32·4	26·5	29·2	27·8	29·2	27·8	29·2	2	1
19	B	16 Jan. 1849	1	37 8 0	30·4	30·8	29·2	29·2	29·2	27·8	29·2	29·2	29·2	3	.
20	B	22 Oct. 1848	2	37 8 3	30·6	30·8	30·8	34·1	32·4	30·8	32·4	30·8	34·1	3	.
21	B	21 Sept. ,,	3	37 18 2	34·5	33·1	34·1	34·1	34·1	32·4	34·1	34·1	34·1	2	1
22	B	6 Oct. ,,	3	38 10 3	34·1	30·8	29·2	29·2	29·2	26·5	25·7	26·5	29·2	2	1
23	B	16 Sept. ,,	3	42 15 2	31·1	32·4	33·4	34·1	32·4	32·4	34·7	33·1	37·0	2	2
		Average Initial Velocity			32·1								31·8	Average Terminal Velocity.	

TABLE VI.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
Class 3.—Speed at the Top of the Incline, from 30 Miles to 35 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.									Remarks.	
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.	Pass. Carriages.	Waggons.
				Tons. cwts. qrs.											
24	T	23 Sept. 1848	3	46 4 0	34·1	34·1	33·1	30·8	29·2	32·4	32·4	29·2	29·2	2	2
25	T	13 ,, ,,	2	46 11 2	30·6	29·2	30·8	26·5	30·8	29·5	27·8	30·8	29·5	2	5 and 1 Horse box.
26	T	29 ,, ,,	2	46 13 0	34·1	29·2	34·1	30·8	29·2	30·8	29·2	29·2	32·4	2	4
27	T	16 ,, ,,	3	46 15 3	31·6	32·4	33·4	30·8	29·2	29·2	30·8	27·8	29·2	2	3
28	T	30 ,, ,,	2	50 1 0	34·1	32·4	30·8	30·8	29·2	32·4	32·4	34·1	32·4	2	4
29	T	27 ,, ,,	3	50 7 1	34·1	29·2	30·8	34·1	30·8	34·1	32·4	34·1	29·2	2	3
		Average Initial Velocity			33·1								30·3	Average Terminal Velocity.	
30	B	20 Oct. 1848	2	45 14 0	31·1	32·4	33·4	31·1	36·3	32·4	34·7	33·1	41·5	2	3
31	B	20 Sept. ,,	3	46 15 1	31·6	29·2	29·2	29·2	29·2	29·2	27·8	27·8	27·8	2	2
32	B	28 ,, ,,	3	51 8 1	34·1	32·4	27·8	27·8	29·2	29·2	29·2	30·8	27·8	2	3
33	B	14 ,, ,,	3	53 14 0	31·1	32·4	33·4	34·1	32·4	32·4	34·7	33·1	37·0	2	3
34	B	25 Oct. ,,	3	54 6 0	31·6	27·8	32·4	27·8	29·2	32·4	29·2	34·7	33·1	2	3
35	B	15 Sept. ,,	3	57 5 0	31·1	32·4	33·1	34·1	32·4	32·4	32·4	34·1	34 1	2	3
		Average Initial Velocity			31·7								33·5	Average Terminal Velocity.	
36	B	2 Oct. 1848	2	64 13 3	34·1	32·4	27·8	30·8	34·1	26·5	34·1	29·2	30·8	2	5
37	B	30 Sept. ,,	2	65 2 0	31·6	34·1	32·4	30·8	30·8	32·4	32·4	32·4	30·8	2	5
		Average Initial Velocity			32·8								30·8	Average Terminal Velocity.	

TABLE VII.—TRIALS made on the VELOCITY of TRAINS down an Incline of 1 in 100, without Steam.
CLASS 4.—Speed at the Top of the Incline, from 35 Miles to 40 Miles per Hour.

No. of Trial.		Date.	Engine No.	Total Load in Tons Moved.	Speed in Miles per Hour. Each Division being over a space of 300 Yards.									Remarks.	
					On Level at Top of Incline.	1st Div.	2nd Div.	3rd Div.	4th Div.	5th Div.	6th Div.	7th Div.	8th Div.	Pass. Carriages.	Waggons.
				Tons. cwts. qrs.											
1	T	11 Sept. 1848	2	32 6 2	35·8	34·7	34·7	34·1	29·2	32·4	31·1	25·7	30·8	2	.
2	T	2 Oct. ,,	2	35 6 1	37·5	32·4	29·2	30·8	30·8	34·1	32·4	30·8	32·4	2	1
3	T	4 ,, ,,	3	42 16 2	39·2	36·3	36·3	36·3	36·3	30·8	32·4	29·2	30·8	2	3
		Average Initial Velocity			37·5								31·3	Average Terminal Velocity.	
4	B	4 Oct. 1848	3	32 3 2	35·6	36·3	32·4	34·1	30·8	32·4	34·1	32·4	32·4	2	.
5	B	26 Sept. ,,	2	32 7 1	35·8	36·3	32·4	32·4	29·2	29·2	27·8	29·2	29·2	2	.
		Average Initial Velocity			35·7								30·8	Average Terminal Velocity.	
6	T	5 Oct. 1848	3	45 11 2	39·2	36·3	36·3	36·3	36·3	30·8	32·4	29·2	30·8	2	4
7	T	21 Sept. ,,	3	57 2 1	35·8	34·7	34·7	34·1	29·2	32·4	31·1	28·0	30·8	2	4
		Average Initial Velocity			37·5								30·8	Average Terminal Velocity.	
8	T	1 Sept. 1848	3	61 10 0	35·2	30·8	33·1	33·1	30·8	33·1	32·4	29·5	30·8	2	4

TABLE VIII.—CLASS 5.—Speed at the Top of the Incline, from 40 Miles to 45 Miles per Hour.

1	T	19 Aug. 1848	3	32 1 0	41·7	36·3	34·7	38·6	34·7	33·1	31·1	28·1	32·4	2	.
2	T	17 ,, ,,	3	35 6 0	44·8	40·4	38·6	34·1	32·4	36·3	32·4	31·1	31·1	2	1
		Average Initial Velocity			43·2								31·7	Average Terminal Velocity.	

Captain W. S. Moorsom said, the experiments he had recorded in this Paper were made upon the ordinary traffic, and were, consequently, more to be depended upon, than abstract experiments. They were eighty-two in number, and were made over two inclined planes of 1 in 100, 2,400 yards in length; the straighter plane had one curve, with a radius of 2½ miles, thus affording some appreciation of the effect of curvature in retarding impulsive gravity. The weight of the engine, carrying its own tender, was 22 tons, the average weight of the unloaded carriages was nearly 5 tons each, and that of the empty waggons 3½ tons each: whenever carriages and waggons were both used, the latter were placed in front, and the area of the frontage was nearly always the same. There were a few discrepancies in the results obtained, but he thought, that on the whole, the average would be found sufficiently regular. The initial velocity was determined by observations made from the commencement of the level up to the point where the action of the breaks would be required. It resulted, not only from these experiments, but from others, that whatever might be the initial velocity, the terminal velocity was always from 28 miles to 34 miles an hour. A speed of 43 miles was found to diminish, and a speed of 20 miles an hour was found to increase. He, therefore, thought any idea, that a speed of 50 miles, or 60 miles an hour could be attained, at least, on an incline of 1 in 100, must be erroneous. A case had come under his notice, where an incline of 1 in 90 was objected to on that score, but the real objection should have been, not the rapidity of the descent, but the difficulty of the ascent.

No. 809.—"Description of the Bridge erected at Athlone, by the Commissioners for the Improvement of the River Shannon." By Lieutenant-Colonel Harry David Jones, M. Inst. C.E.*

The old bridge at Athlone was erected in the reign of Queen Elizabeth, and consisted of ten arches, with a roadway of 13½ feet in width. The ground chosen for the new structure, was a short distance higher up the stream, in the gorge of one of the great 'Eschars' which, in this locality, rise to a height of 170 feet above the river, and through which the Shannon, which is here about 300 feet wide, appears to have, at some remote period, forced

* To this Paper was appended a copy of the printed specifications, the Author considering, that they would afford the best account of the construction of the works, as no material alteration was made during their progress.

its passage seaward. "Eschars are gravel hills rapidly deposited from water in violent action, frequently consisting of large masses of rock, partially rounded, intermixed with small gravel and even clay and sand." Such material forms, in general, an excellent foundation, but it admits percolation so freely, that the draining of coffer-dams constructed upon it, must always be attended with considerable difficulty and expense.

In the month of May, 1841, the works were let by contract to Mr. John MacMahon. His first operations were the erection of a steam-engine of 12 H. P. for draining the coffer-dams and for grinding hydraulic mortar, and of staging across the river for the waggon and gangtree roads. This being accomplished, the driving of the piles, for the coffer-dam of the eastern abutment, was commenced, in the latter end of June, and the works proceeded with energy; the excavation within, having been completed very shortly after the erection of the dam.

Considerable difficulties, however, presented themselves in the construction and draining of the dams, owing to the frequent occurrence of large boulders, resisting and deranging the driving of the piles; and the facility with which, as has been already observed, the seams of open gravel allowed the water to pass from the high ground bounding the site, through subterraneous channels seated far below the bed of the river. From these chambers, the waters of the Eschars, at times pent up to a great height, would frequently burst with much force, within the dams, although the piles were driven fully 13 feet below the bed of the navigable channel. On these occasions it required all the power at command, to keep the water in subjection, though in some instances, unfortunately, the inflow was so great, from the sources already described, that the dam would fill with water and fine silt, which had to remain untouched for four, or five days, until the supplies were lowered, when the deposit of the silt choking up the orifice, through which the water rushed in, the work could be resumed. The Contractor, however, who with great talent, combined extensive practical experience, succeeded in overcoming this difficulty, as above stated, and from the skilful manner in which he constructed his dams, he was enabled to make good progress during the year.

The first stone of the eastern abutment was laid on the 6th of November, and the masonry was proceeded with until the month of December following, when the height of the floods rendered it necessary to suspend the building operations for the winter. The coffer-dam for the western abutment, which was at the same time in progress, was completed during that season. Mr. MacMahon

suggested an alteration in the mode of constructing the dams, which was sanctioned by the Commissioners and proved highly satisfactory, allowing much greater expedition to be used, than with the original design, and although equally efficacious, it was less expensive in the proportion of five to seven.

In 1842 the floods having subsided, and the dams, throughout, being carried to the level of the springing of the arches, the piers and abutments were steadily carried on, the three stone arches progressed regularly towards completion, and the retaining walls for the approaches were raised to the level of the roadway. The castings for the iron arch of the swivel bridge, were delivered on the works and partly fitted into the masonry, in the course of this year.

By the end of October, 1843, the masonry was in a very forward state, and the swivel bridge castings were nearly all fixed.

During the summer of 1844, the whole of the works were completed, and on the removal of the temporary fences, Mr. Rhodes reported to the Commissioners, that the undertaking was finished in a most substantial and satisfactory manner, both as regarded workmanship and materials. The bridge was thrown open to the public early in the month of November of that year.

The material used was carboniferous limestone of a very fine quality, weighing 168 lbs. to the cubic foot. The stones, when dressed, presented a beautiful gray colour, which gives the bridge a handsome appearance. The quarries from which they were procured, were those of Lecarrow in the county of Roscommon, and of Cashel in the county of Longford, about nine miles above the town of Athlone, on the shores of Lough Ree. So compact and homogeneous in its nature, was the stone of Lecarrow quarry, that with a well-calculated charge, a block of one hundred tons has been sufficiently removed, to admit of being worked into numerous ashlars of the required dimensions, many weighing upwards of five tons. There was also another quarry, named Ballykeeran, in the county of Westmeath, about three miles from Athlone, producing stone with strong hydraulic properties, which was employed with great advantage in the mortar for the structure, and as a building material for those portions of the work that did not require hewing.

The contract for the works was entered into, for the sum of £23,000: the actual cost, including all extras, was £24,209 17*s.* 2*d.* The great benefit the public derive from the execution of this bridge, may be readily understood from the fact, that the breadth of roadway is 32 feet, whilst that of the old bridge was only 13½ feet.

It may be proper here to observe, that the contractor, instead of constructing new centres, was allowed to alter and to use those that had been in requisition at Banagher Bridge, the arches of which were one foot less than those of Athlone.

The plans and specifications having been so well considered in the first instance by Mr. Rhodes, very few alterations, or deviations became necessary. It was originally intended, that there should be, in the centre of each of the piers, and in the eastern abutment of the bridge, a cast-iron pipe, 6 inches in diameter, communicating with a transverse pipe, or covered drain, extending across the road from one channel to the other, and laid so as to convey the water from each channel, through the pipe, into the river. It has been a subject of much regret, that these cast-iron pipes were afterwards dispensed with, as the stone which was cut to receive them not having been properly lined with cement, there has been in one, or two places during wet weather, a weeping through a portion of the external spandrel walls, which has dimmed, in some degree, the lustre of the façade: this defect, however, is expected to be remedied in the course of the approaching summer.

Preceding the extracts from the Commissioners' Minutes given in the Appendix, it is desirable to insert a portion of a communication received from Mr. MacMahon, the Contractor, in which he suggested the alteration in the construction of the dams, and the principles on which his views were founded:—

"The usual mode adopted by Engineers in constructing coffer-dams, is to drive the gauge piles of whole balks, to the required depth, 10 feet apart in the clear, the breadth of the coffer being governed by the pressure of water from without. When the dam is empty, the minimum breadth given to insure a staunch puddle-bank is 5 feet.

"In the dams driven in the Liffey, in the year 1817, under the direction of the late Mr. Rennie, the clay puddle, 6 feet in thickness, was carried from a dredged channel in the bed of the river, to the high water of neap tides. From that level to 1 foot above high water of extraordinary springs, the coffer-dam was filled with brick, bedded and jointed in fine sand. The double wale pieces were of half-balks notched, so as to reduce the space, through which the sheet piles were driven, to 6½ inches. By this proceeding the range of each cant of the dam was divided into 10-feet bays, in each of which key piles were fitted and driven to close home the sheet to the gauge piles.

"Wale pieces, in dams of this construction, cannot be placed in tideways below the lowest ebb, nor in rivers below summer water

level, thus leaving, in deep foundations, a great portion of the dam without support.

"The through-bolts, driven through the front and rear rows of the gauge piles, to give the frame additional strength, are, in all cases, productive of mischief; the incumbent puddle, or brick superstructure in the coffer, as the case may be, has a natural tendency to subside, but the through-bolts sustaining a portion of the materials, destroy the connexion, and of course, the staunchness of the dam.

"To provide against such difficulties as are here referred to, I propose, with the sanction of the Commissioners, to construct the Athlone dams on principles differing from those prescribed by the contract, and stated in the foregoing part of this letter.

"By the arrangement which I take leave to submit, I calculate on saving timber, iron, time, and as a necessary consequence, expense, in the proportion of seven to five in constructing the proposed dams, besides adding importantly to their strength, above those hitherto in use.

"The spaces to be enclosed for piers, or abutments, having been decided on, I purpose driving the gauge piles in the usual way, 10 feet apart in the clear, and of sufficient lengths to stand, when driven 2, or 3 feet above high water. The single permanent wales, which are to be of whole balks, three in number, are to be fixed at suitable levels on the back of the gauge piles, or side most remote from the enclosure, by the simple contrivance of spars of the required lengths, fastened by 'dogs' to the wale pieces. These wale pieces are then to to be sunk to the level deemed most advisable, the lowest being as near the bed of the river as circumstances will allow,—the second about two-fifths the height, to winter floods,—and the upper one to be firmly bolted to the gauge piles at the level of 1 foot above summer water.

"The next operation is to put on two tiers of temporary wales, moveable at will, which are to form the pannels in which the sheet piles are to be driven. To save cost in the fitting of key piles, the frame is first to be completed, and the driving on each side to commence at opposite corners of the dam, so as to close by one key pile at the meeting; the short piles to be roughly jointed and driven closely together; the width of the coffer to be 6 feet. The outer gauge and sheet piles, may be of inferior material to what is used in the inner row, as it is merely to sustain the puddle-bank; the stability of the structure mainly depending on the inner row of gauge piles and wales, as applied with the usual cross and longitudinal braces within the dam.

"I do not intend to pass any bolt, or tie of either wood, or iron,

through the coffer, in order to avoid the annoyances I have already shown them to occasion, when subsidence takes place in the puddle."

The Paper is illustrated by six drawings (Nos. 4,452—4,457), giving the plans and elevation, with longitudinal and transverse sections, sketches of the centering and the coffer-dams, and the sections and details of the swivel bridge.

APPENDIX.

Extracts from the Commissioners' Minutes.

As the bed of the river was found to consist of materials of different degrees of compressibility, one portion of it consisting of coarse clean gravel, and the other of stiff tenacious clay, the following alterations were ordered, in the construction of the foundation.

"The bearing piles and sheeting piles, with the wales and concrete, and also the timber platform, under the southern wing wall, and under that part of the abutment, including the southern cutwater, at which the natural surface of the gravel is above the level of the bottom of the lower footing courses, together with the sheeting piles and wales, extending from the north-western to the north-eastern corner of the abutment, shall be dispensed with.

"The Commissioners having had under consideration a report from Mr. Rhodes, on the subject of the substitution of rubble masonry instead of concrete, between the piles and sleepers in the foundation of the eastern abutment of Athlone Bridge, and stating, that he was willing to adopt the same without any extra charge, it was ordered:—That after the piles in the foundation have been cut off, instead of concrete being introduced between the piles and sleepers, for the depth of 1 foot 6 inches, a pavement of flat-bedded rubble stone should be put in, set on edge, and well driven down with a pavior's rammer: this being considered more durable than a body of concrete, composed of lime and gravel, as the lime would be very liable to be washed out, by the continued stream of water which rushes through the gravelly part of the foundation.

"The contractor having stated, that it would be attended with considerable risk and expense, to lower the foundation for the western abutment for the swivel bridge, to the specified depth, after considering the same, it was ordered: —That the foundations should be laid at the level of 1 foot below the bottom of the navigable channel, secured by the necessary piling and platform as proposed by Mr. Rhodes.

"It having been proposed, to dispense with two of the footing courses in the eastern pier of the Athlone Bridge, the Commissioners approved of one footing course 15 inches in thickness being dispensed with, and the timber platform being raised accordingly, and also that the rubble-stone pitching be substituted for the concrete, between the piles shown upon the contract drawings; this pitching to be closely packed and forced into the clay underneath: in the execution of the works, care to be taken, to keep the water free from the site, upon which the platform is to be laid by means of a tap, or drain to be carried along the sides of the coffer-dam, which tap is to be 2 feet, at least,

clear of the sheeting piles in the foundation, and the bottom of it not less than 12 inches below the bottom of the sleepers."

In consequence of the numerous blows from the water within the coffer-dam of the eastern pier, it was found necessary to increase the length of the piles at the discretion of the Resident Engineer, according to circumstances.

"*September 8th*, 1842.

"With reference to the Commissioners' Minute of yesterday's date, directing certain alterations to be made in the foundation of the eastern pier of Athlone Bridge, the following regulations are to be observed in constructing the foundation:—

"The sheeting piles, wales, sleepers and concrete, shown upon the contract plans, for this foundation, are to be dispensed with.

"The inner row of piles in the coffer-dam and of the gauge piles belonging thereto, which are under the level of 2 feet 9 inches below the datum level, are to remain in the bed of the river. On the inside of the sheeting piles, a waling, 13 inches by 6½ inches, extending round the whole dam, is to be made fast with 12-inch jagged spikes, the top of the wale to be 4 feet 10½ inches below the datum level, the wale pieces to be scarfed at the joinings, the space between the wale pieces and the sheeting piles of the foundation, to be paved with scappled stone pitching, 18 inches in depth, and the joints well filled with sharp sand. In the foundation there are to be sixty-eight bearing piles of beech, which are to be of such lengths, not less than 10 feet, as the Commissioners' Engineer shall direct. Upon these bearing piles seventeen Memel sleepers are to be laid, five of them of whole-balk timber, 13 inches by 13 inches, and the remaining twelve of half-balk, 13 inches by 6½ inches; these sleepers are to be laid in a direction transverse to the pier, and their upper surfaces to be 4 feet 4 inches below the datum level; each of the whole-balk sleepers is to be laid between any two opposite gauge piles, in the dam, into the side of which gauge pile the sleeper is to be notched for half the depth of the pile, and made fast thereto by two bolts, having suitable nuts and washers. In each of the spaces, between these, whole-balk sleepers which at each of their ends are to be made fast to the wales, already described, with 12-inch spikes. The sleepers are to be thorough, and of such lengths as that they will touch the sheet piles at each side of the dams, when fixed, and they are to be made fast to each of the bearing piles which they cross with jagged bolts,—the whole-balk sleepers with 18-inch bolts and the half-balk with 12-inch bolts; upon these sleepers the planking already provided in the specification is to be laid; the planks to be laid in the longitudinal direction of the pier. In all cases the ends of the planks are to meet at the centre of a whole-balk sleeper, and to be of such lengths as that they will cross, at least, three of those sleepers.

"Previous to laying down the sleepers, the foundation for the whole extent of the space within the dam, is to be filled to within 2 feet of the under side of the planking, with rubbish, consisting of boulder stones and coarse gravel, such as will be obtained at the south end of the dam. Over this filling when carefully rammed down and levelled off, this space is to be pitched to the under side of the sleepers with large flat-bedded stones laid on edge and closely and solidly packed, the sleepers are then to be laid down as herein-before directed and the spaces between them filled with gravel. The lower of the two footing courses is to be 15 inches in thickness, and is to be raised so that its top shall be 2 feet 9 inches below the datum level; and the space around this footing course, and between it and the sheeting piles, is to be filled with

boulder stones and gravel, such as is already directed for the filling under the pitching. As regards the additions, or deductions to the contract that may be involved in the alterations ordered in the minute, the Commissioners agree to the proposal made in Mr. MacMahon's letter of the 4th instant, that the portion of the dam which is to be left in the bed of the river is to go in exchange for the sheeting piles and wales dispensed with, and that the bearing piles, sleepers, planking, concrete, pitching, excavation, &c., be calculated according to the quantity contained in them."

Mr. CUBITT, *V.P.*, said, he was one of the Shannon Commissioners, and in that capacity had rendered himself acquainted with the locality and the bridge itself, which he considered a good structure.

Captain W. S. MOORSOM said, he had also seen the bridge, since it had been opened; it was an excellent structure, and he was surprised that the expense of it was so small. It had been said, that the opening arch had not been placed in the most judicious position for the channel; indeed, it appeared from the drawings, that the channel was deeper in another part: it had also been said, that an artificial channel had been created for some purpose; it was, therefore, desirable that these points should be explained.

Mr. WALKER thought, the reasons for the situation of the opening arch and even for cutting an auxiliary channel were very evident. The river was subject to floods, and it would not have been judicious to place piers of the size necessary for the swing bridge, in the middle of the channel; indeed, it would appear, that the piers which were necessarily placed in the stream, impeded it so much, that it was considered prudent to cut a side channel to take a portion of the waters, and through that the navigation was conducted, finding there less resistance in passing the bridge.

Mr. Walker could not approve of the absence of transverse ties in coffer-dams of any magnitude; it would be hazardous and without any commensurate advantage. It would be more important to get rid of inner wales, if possible, as when the puddle sunk from them, leaks frequently occurred.

Mr. W. RADFORD observed, that in such a limited depth of water as only 6 feet, or 8 feet during floods, which was the case at Athlone, through-bolts might be dispensed with in the coffer-dams; indeed, he thought they might have been made of single rows of sheet piling, well driven and close jointed, without puddle; but in coffer-dams of magnitude, such for instance, as those constructed under Mr. Walker's directions at Blackfriars Bridge, it would be dangerous to

have dispensed with cross bolts. Those dams were composed of two rows of whole-timber piles, driven at intervals of 6 feet from centre to centre, longitudinally, and 8 feet apart, transversely, with whole-timber walings, and two rows of half-timber sheet piles, retaining a thickness of 5 feet of puddle, which was carried down to the natural clay. The height from the bed of the river, to the top of the dam, was upwards of 30 feet, and the piles were generally about 45 feet long, yet the dams, when finished, were so perfectly tight, that one labourer, with a hand-pump, kept each of them quite dry. In these dams, the lower tie bolts, which were of round iron 1¼ inch in diameter and placed at intervals of 6 feet longitudinally and 18 feet down, were frequently fractured by the pressure of the puddle. In the construction of these dams the utmost economy of material was practised, consistent with the nature of the work.

The system of making the walings was not novel, as it had been used at Blackfriars Bridge, where the wales were sunk to 6 feet below low water, to stiffen the sheet piling.

June 19, 1849.

JOSHUA FIELD, President, in the Chair.

No. 810.—"On the Employment of High-pressure Steam, working expansively, in Marine Engines."* By John Seaward, M. Inst. C.E.

[ABSTRACT.]

THIS communication was described to be the substance of a reply, by the Author, to some questions addressed to several eminent engineering firms, by the Hon. H. L. Corry, M.P., when Secretary of the Admiralty. This reply was found to furnish so much useful information, and so completely to open the question of the advantage, or disadvantage of using high-pressure steam, and of cutting off the steam at various portions of the stroke, that it was conceived it would be advantageously produced at the Institution, in order that the subject should be fully discussed.

The Paper first reviewed the mode of working marine engines, for some years past, and noticed the gradual change that had occurred, particularly the tendency to use high-pressure steam, instead of that of a pressure of about 4 lbs. above the atmosphere. It then examined the system of cutting off the steam at various parts of the

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* The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

stroke; and as, at the same time, a remarkable augmentation had occurred in the speed of the vessels, which was naturally attributed to that cause, it inquired minutely into these several causes and effects, as well as the considerable reduction in the consumption of fuel which took place, enabling the vessels, consequently, to make longer voyages, or to carry less fuel for given distances.

In this examination, all the arguments for and against the use of high-pressure steam, and the presumed gain, or loss of mechanical power in the use of the expansion principle in the cylinder, were canvassed at length; and the Paper concluded with the replies of the Author to the three questions from the Admiralty, to this effect:—

"The highest pressure of steam that we have, in any case, put upon a marine boiler of our own construction, was about 16 lbs. to the square inch; but we are not inclined to repeat the experiment, as we feel assured, that we can obtain equally good results with steam of a lower pressure: from 10 to 12 lbs. is the usual pressure we employ in the merchant service, for engines and boilers of comparatively small power.

"The steam pressure, at present employed in the service, is about 8 lbs. per square inch. We consider steam of this pressure to be well adapted for the exigencies of the service; we believe it is calculated to secure all the important advantages of power, and economy of weight and space, in a very eminent degree: these advantages will, in some respects, be slightly increased, by augmenting the steam pressure to 10, or 12 lbs. on the square inch.

"We strongly recommend, that the steam employed in the navy should not be of greater pressure than 10 lbs. per square inch, or in extreme cases, 12 lbs. to the square inch: any material increase to the latter pressure will be attended with considerable risk, without any adequate advantage."

Mr. Scott Russell could not entirely subscribe to the whole of the deductions from the reasonings, particularly the statement of the presumed economy, consequent on the use of steam at a pressure of 40 lbs. per inch, as compared with steam at 20 lbs. per inch. He must, on the contrary, contend, that a given volume of steam at 40 lbs. pressure, would not expand to double the volume of steam at a pressure of 20 lbs., nor would it, when expanded, produce the increased amount of useful effect, over a given volume of steam generated at 20 lbs. pressure: this was susceptible of easy practical proof. The Paper had given a correct representation of the opinion of the profession on the important subject, of the degree of pressure

which should be used, and how far the steam should be worked expansively. It was generally admitted, that especially for boilers working with salt water, a high temperature was dangerous and injurious, besides inducing speedy decay: to these objections was further added the danger from incrustation, when working under the circumstances of high pressure and high temperature, affording serious arguments against the use of high pressure in marine boilers. There was another point which, in his opinion, was an important objection to the use of steam of very high pressure for marine purposes; it was the want of continuity in the action of the expanding steam through the paddle-wheels, on an inelastic fluid like water. Every one who had investigated the action of an ordinary expansive engine upon water, through the medium of the crank, must have noticed, upon an indicator card, that the effect given out at the extremity of the paddle-wheel, formed as ugly and ill formed a figure as could be conceived. The peculiar faults of the crank were greatly exaggerated by the use of high-pressure steam, worked very expansively, and it became apparent, that considerable positive loss ensued, from the irregular action of the paddles on the surface of an inelastic fluid. The nature of the loss was, that when, under the most rapid action of the highest steam, combined with the greatest leverage of the crank, the paddle-wheel was giving out, for an instant, a maximum effect, it produced, for that instant, a great result; when, however, the paddle, which had communicated a great velocity to all the particles of water, upon which it acted, began to lose its actual power, and this diminution continued until the end of the stroke, the water reacting at the same time upon the paddles, the amount of reaction was in proportion to the previous useful effect. The consequences were felt in the succeeding stroke, which, in addition to its own work, had to compensate for the previous effect of retardation; he contended, therefore, that it was unsatisfactory to apply a very variable pressure to a machine acting on a fluid like water. He thought these important considerations had weighed with Engineers, in deciding them against recommending, in the ordinary marine engine, the use of very high steam.

Another argument was, that as the pressure increased, so was the temperature raised in the boiler, and the danger from explosion, caused by incrustation, was augmented: the wear and tear, and destruction of boilers, from that cause, when working in salt water, must also be taken into account. He believed, that these considerations had mainly operated in the minds of Engineers, and induced them to view with jealousy, the professed advantages of high-pressure steam, and had prevented professional encounters of

skill which could only have the effect of endangering life and property.

Mr. RENNIE concurred, generally, in the conclusions of the Paper, on the complicated question of the use of steam of a higher pressure, and he thought the hesitation on the part of English Engineers, as to its general adoption, was characteristic of that sound practical caution to which they owed much of their reputation; and in which they were fully justified, when the lamentable loss of life and property which occurred in the United States, from this cause, was duly considered. The advantages proposed were fully counterbalanced by this consideration.

The progress of steam navigation, in later years, was mainly due to the improvement in the forms of the vessels, the introduction of tubular boilers, and the lighter, yet stronger construction of the engines; and as every day's experience induced fresh alterations, it would be presumptuous to limit, even in idea, the progress of this interesting branch of engineering. On the subject of boilers there was much to be said; the square form required to be supported by a number of stays, which, added to the weight, complicated the construction, and caused a difficulty in cleansing, especially when working with salt water: on the other hand, the circular form had, generally, some weak point, where the boiler was liable to fail. Still he thought a partly cylindrical boiler might be contrived, which would meet all the requirements.

The late Mr. Cockerell, of Liège, had tried many experiments on the forms and proportions of boilers, and he had observed, that a plain cylindrical boiler, the length of which was six times its diameter, evaporated the largest quantity of water, under the best circumstances, and the air quitted the flue at a temperature varying between 700° and 800°. Such proportions were not applicable for marine boilers; but the results obtained might lead to modifications, which might conduce to the more efficient and safer employment of high-pressure steam, and at the same time, to the reduction, rather than the increase of the weight of the machinery. Mr. Rennie did not think the argument in the Paper, as to the increase of weight of the machinery, being in proportion to the pressure, was altogether well founded, as the weight of marine engines had actually decreased, within the last few years, almost in the ratio of the practical augmentation of the pressure used.

Mr. Fox thought, that it had not been pointed out with sufficient clearness, in what the great difference between the action of the marine and the stationary engine consisted. To a stationary engine there was appended a fly-wheel, and to a pumping engine there was a

heavy plunger rod, both of which aided the return action; but a marine engine was divested of these aids, and, when working expansively, there was an irregular impulsive action, communicated through the crank to the paddles, expending itself, also, irregularly, upon an inelastic fluid, without the intervention of anything like a reservoir of power; therefore, the exertion of this power must be considered under a different view, and be treated according to the circumstances under which the steam-engine was applied.

In a marine engine, working expansively, a certain effect was produced by the first impulse on the piston; and as soon as the flow of steam was cut off and expansion commenced, the effective power diminished, but the opposing force was permanent, and thus the action became very different from that in a locomotive, where the weight of the engine and train, and the momentum acquired, aided the expansive action, assuming that the adhesion of the wheels was sufficient to absorb the power given out.

Mr. FIELD,—President,—said there was a prevalent opinion, that high-pressure steam necessarily implied more power developed. This, however, was a mistake, for if steam of higher density were generated, the quantity was less in proportion as the pressure was increased, and thus the power remained the same. The condensing engine had the advantage of acting upon a vacuum, whilst the high-pressure engine had the waste steam to blow the fire, by the blast in the chimney. These might be considered to balance each other, but the high-pressure boiler was much more intensely heated, and consequently, more rapidly burnt out. The great pressure required that the cylindrical form should be used, whilst the low-pressure boiler might be rectangular, and thus economize space: an important consideration in steam-vessels.

Mr. FAREY thought, that the rapid succession of the strokes obviated the objection raised by Mr. Scott Russell. The experiments with steam at very high pressures, in locomotive engines were so encouraging, as to justify the employment of it in marine engines; but the experiments should be made gradually and cautiously, recollecting the numerous accidents continually occurring on the American rivers, from the use of steam of very high pressure.

Mr. HOMERSHAM said, that the Paper only alluded to condensing engines, in which the advantages of employing steam of a high pressure were very limited; he believed, that the advantages would be much greater in non-condensing engines, and that light high-pressure engines working expansively, might and would be used for river boats.

Mr. CRAMPTON said, the question between high-pressure steam

and low-pressure steam, was entirely different, when considered in reference to locomotives, or to marine engines. In locomotives, the greater the pressure and the expansion at which it was used, the greater was the useful effect of the steam: with a high-pressure engine, therefore, the steam should be as high as possible, and it should not be forgotten, that in non-condensing engines the pressure of the atmosphere was lost.

Mr. PERKINS, through the Secretary, expressed his dissent from the opinion, given in the Paper, that steam for marine purposes, should be limited to 10 lbs., or 12 lbs. to the square inch, on account of the presumed danger of generating steam beyond that pressure.

It was now twenty-five years since his Father proved, that steam could be generated with perfect safety, under a pressure of 500 lbs. to the square inch, and the steam-gun was an evidence of the fact. Boilers might be constructed, sufficiently strong to bear any amount of pressure; they could, if necessary, be made as indestructible as the cylinders of the steam-engine.

Mr. FIELD,—President,—said, that locomotive boilers on board steamers would, no doubt, generate sufficient steam; but the long duration of ocean voyages, in which sea water alone could be used, rendered their success exceedingly doubtful. Tubular boilers, when used at sea, should have longer tubes, and much more water space than were required in a locomotive engine, which had only to run for one, or two hours at a time. Although cylindrical boilers were the strongest form, yet space was so important on board ship, that this form would not give capacity enough, and rectangular boilers were found more convenient. They should be well stayed, and if the steam did not exceed 20 lbs. on the square inch, they might be made and worked with safety, provided they were proved by water pressure, to two, or three times that amount. The old engines and boilers lasted much longer than those of modern date, because the steam used was at a pressure of about 5 lbs., whilst the general proportions of the engines as to strength were much the same as at present. Modern engines being generally worked with steam of a pressure of from 10 lbs. to 20 lbs., and at nearly double the speed, often realized three times, or four times their nominal power: they must, necessarily, be more exposed to fracture, would wear out much sooner, and if not carefully constructed, be more liable to accidents from explosion, &c.

June 26, 1849.

JOSHUA FIELD, President, in the Chair.

The following Candidates were balloted for and duly elected:—Edward Ladd Betts, and William Coulthard, as Associates.

No. 800.—"On the Obstructions to Navigation in Tidal Rivers." By John Thornhill Harrison, M. Inst. C.E.

THIS subject naturally divides itself into the two considerations of the powers of the solid materials which form the obstructions to navigation; and the action of water, which is the chief agent in giving motion to those materials. It is proposed to consider first, in a general manner, the circumstances which affect the deposition of the solid material and the action of the water,—and secondly, to apply these circumstances, in explanation of the formation of obstructions existing in the bed and at the entrance of tidal rivers.

1st.—The obstructions to navigation are composed of the solid materials of the earth, which being deposited in various localities, form banks of gravel, sand, or mud; thus lessening the depth of water and becoming detrimental to navigation.

Now these materials, as usually met with, composing the crust of the earth, are in a compact form, the particles being held together by their cohesion. When the cohesion of the mass is destroyed, and the materials are broken up into small fragments, the friction of one part against another, prevents the whole from assuming a level surface and being drawn by the force of gravity, as nearly as it can be, to the centre of the earth, like water, which is, in a great measure, devoid of cohesion and friction. The limiting angle, at which various kinds of solid materials stand erect, or at given angles, is thus soon attained, and the application of force is necessary to move them from their position.

Water soaking into materials frequently lessens the cohesion of the particles; it also diminishes friction, so as to cause the motion of solid bodies, by which they are brought within range of the action of water in motion. Land-slips, falls of cliffs, &c., are the frequent effects of these causes. In cases where the cohesion is entirely destroyed, the material, when mixed with water, becomes semi-fluid, and will only rest in a horizontal position. A very slight movement of the water is sufficient to disturb it from its state of rest, whereas it requires greater velocity to communicate motion to

materials of a coarser description: thus it is found, that water moving with the velocity of

3 inches	per second,	will move	fine clay.
6 inches	,,	,,	fine sand.
12 inches	,,	,,	fine gravel.
36 inches	,,	,,	stones, the size of an egg.

The specific gravity of the material must, however, influence the degree of velocity required to move it.

As it requires these several velocities to communicate this motion, so when the velocity is lessened, below the required degree, the motion given rapidly ceases, and the body remains in a state of rest, if it has been rolled along the bottom, or it gradually subsides, when it is held in suspension, the very fine particles requiring a nearly quiescent state of the water for them to subside in.

The sources, from which the material, thus subjected to the action of the water, is derived, are the surface of land drained, the sides of the valleys, through which the rivers run, and the cliffs bordering on and subject to the violent action of the sea. The quantity and quality of these materials depend very considerably on the geological character of the country from which they are derived. For instance, the material brought down by rivers, passing through a lias district, will be, to a great extent, of a muddy nature and large in quantity; thus the Severn and the Humber are remarkable for the muddiness of their waters. On the contrary, when the river passes through a district of the older and harder formations, the quantity of material is less, but it is much coarser, and consequently, less easy to move; the greater inclination which such rivers generally have assists, however, the removal.

The rocky bed of a river frequently presents obstructions to navigation. Piers of bridges, weirs, quays, &c., are also often found obstructing, or causing obstructions in the course of a river.

2nd.—It is proposed to consider the action of water, which is the chief agent in giving motion to the materials which cause the obstructions.

The most simple case, which claims attention, is that of water flowing down an inclined plane, under the action of gravity, the course being straight, the width, depth, and inclination uniform, and the friction on the sides and bottom very small; the velocity of the fluid would then be uniform, the motion of each particle being dependant upon the inclination of the bed of the stream. This would be pure stream motion.

Friction here performs a very important part, in limiting the

velocity. As the depth of the water increases, the velocity of the stream increases likewise, for the friction is only as the length of the bottom and sides of the cross section, whilst the accelerating force is as the area of section of the stream.

Thus it is found, that

$$V \text{ the velocity, in inches, per second} = \frac{10}{11}\sqrt{I \times \frac{A}{L}}.$$

A being the area, in square feet.

L being the length of the sides and bottom, in feet.

I being the fall in 2 miles, in inches.

A curve in the channel deflects the water from the straight line, in which it would otherwise run, the effect of the centrifugal force of the water being to heap it against the concave side of the stream; the depth of water there is thus increased, and consequently, its velocity. The cross section of the river, therefore, becomes AB, as in Plate 9, Figs. 1 and 2, with a tendency always to encroach upon the concave shore.

Forced motion of water exists, when the momentum of one section of particles is transmitted to those adjoining, by them again to the next, and so on successively. The principal causes of this forced motion, the effects of which are to be considered, are,—the attraction of the sun and moon on the waters of the earth, generating the great tidal wave, a part of the momentum of which is destroyed on the coast and up the estuaries: and the wind acting upon the waters of the ocean, generating the waves which lash the shores, and expending their violence upon them.

The effect of water running down an inclined plane in a pure stream, and transmitting its momentum to water, comparatively quiescent, may be a wave form of the surface of the water, moving in the direction of the momentum transmitted, sometimes barely perceptible, as when water falls in a constant stream into a pond, or reservoir; or the surface may assume the form of standing waves, when the water, into which the constant stream falls, is not sufficiently deep for the free transmission of the momentum. In all these cases there is a forced motion of the water, and the momentum is transmitted from particle to particle: wave motion of the surface may, or may not, be perceptible, but the motion given to the water is of the same character.

The varieties in the wave effect seem to be dependent upon the depth of water, to which the momentum is communicated, and the manner in which it is generated, according as the quantity of water, or its velocity, is the principal element.

In Mr. Scott Russell's experiments on the wave of translation,

he found, that a subsidiary positive wave of translation, was generated, when the quantity of water, used in the process of generation, was too great, and that a subsidiary negative wave of translation was generated, when the quantity of water was small; but its velocity, (by falling from a greater height,) was considerable. In the generation of a wave of translation, the momentum is a maximum at about one-third of the fall, from which the height of the wave is determined, and a wave of translation to be in equilibrium, will assume a certain definite form, dependant upon the momentum and the depth of the water, along which it passes. Now in the former of Mr. Russell's experiments, after this maximum is attained, the pressure is kept up, for a longer time than is necessary for the formation of the pure wave, and the subsidiary positive wave is the consequence. In like manner, in the second experiment, a less velocity is given to a greater quantity of water, than is contained in the generating column, and the water falls lower, than the general level of the water, causing thereby the subsidiary negative waves.

The transition from the consideration of the genesis of a positive wave of translation, with a subsidiary wave of the same kind, to the case of motion transmitted by a constant supply from a head of water, appears easy. At first, there would be the propagation of a wave in front, with a crest above the general level of the water: this wave proceeding by itself, would be followed by a body of water, with a wave-shaped front and an undulating surface behind, the level of the succeeding waves being lower than the crest of the fore-running wave, but higher than that of the water, before the head began to flow, (Fig. 3). Both in the first wave generated and in the succeeding wavy surface of the water, the motion of the water is forced.

Again, when the velocity of the water from the head is considerable, and the whole of it is required for the formation of the generated wave, the production of the standing wave appears to be the consequence. In this case there are alternations of free and forced motion; the water by falling freely from one wave expending its momentum in maintaining the head of water at the next; each successive wave lessening in height, partly from the diminution of the momentum by friction, and partly from its being transmitted to a larger body of water. This process continues until, by degrees, the original momentum is altered, from being composed of a small quantity, at a great velocity, into a larger quantity, at a less velocity. Are not the secondary waves which accompany Mr. Russell's negative wave of the first order, similar in character to standing waves? the only difference being, that the head of water in the one case is stationary,

and in the other moveable. Now as wave motion is caused by momentum, transferred from one section of water to another, and such transfer is effected without much diminution of the quantity of momentum, it follows, that as the section of water diminishes, the velocity given to it increases, and *vice versâ*. Therefore, supposing the longitudinal section to be as shown in Fig. 4, and the width to be uniform, the water would have considerable velocity over the shallows and a less velocity in the deeps. The velocity of transmission of the momentum is increased by the greater depth of water; this gives rise to an increased rapidity of the wave form of the water. The momentum of the water is diminished by the friction on the bottom, and by curves, which cause a constant expenditure in diverting the water from the straight course. It seems to be very little diminished by transmission from particle to particle.

Having enumerated some varieties in the motion of water itself, the effects of its motion on the materials subjected to its action, come next to be considered.

It has been shown, that water running freely under the action of gravity, has the greatest velocity in the deepest channel, and a less velocity where it is shallower; the tendency of the solid matter carried down by it will therefore be, to settle in the shallow parts more than in the deep ones. Thus at A, (Fig. 5,) the velocity of the water is the greatest, the tendency to deposit is the least, and the material deposited, or left unmoved, larger: at B the velocity of the water is the least, the tendency to deposit is the greatest, and the material deposited more minute.

When the water leaves a curve, and the course becomes straight, the cause of the increased velocity on the concave side of the channel no longer exists; the consequence is a diminution of velocity and the deposition of the material carried along, which forms a shoal, across which the water frequently passes nearly at right angles to its former course, the largest detritus lying nearest A, (Fig. 6,) towards which point the current had been strongest, carrying with it the largest materials. The tendency of the cross current over the shoal is to encroach on the bank, making a reverse curve with a shoal between the curves as shown by the dotted lines. Shoals thus formed are found in most rivers at the junction of a curved with a straight course, or when one curve joins another in the opposite direction.

When a pure wave of translation is passing up a river and the cross section of the channel changes from the dotted to the black-line section, within a short distance, (Fig. 7,) the velocity of the water, over the shallow, will be greater than in the deep, and there will be

a tendency to scour it and carry forward the material to a situation where the water is deeper, and its velocity, in consequence, diminished. Thus at A, the velocity of the water is the greatest, and at B, the least. This, it will be observed, is the reverse of the effect of water flowing freely under the action of gravity.

When the longitudinal section presents a succession of deeps and shallows, the tendency will be to scour the shallows and deposit the material in the deeper parts. There would, at the same time, be a considerable loss of momentum from friction, and the height of the wave would be greater at each shallow. If such a shoal as A, (Fig. 7,) be of some extent, and the depth of water small, the momentum of the water passing over it is diminished as it proceeds, by the friction on the bottom; there will, consequently, be a tendency to deposit the matter at first moved. The shoal thus raised leaves room for a less quantity of water to be acted upon, from which cause it will be forced up the incline to a higher level, the result being, that such a bank, on the longitudinal section, assumes the form shown in Fig. 8; the velocity of the water over it being constantly subject to an increase from the diminished depth, but to a greater decrease, from the friction, and from being raised up an inclined plane.

When standing waves are formed, there is a tendency to deposit at each of them, the velocity of the water then being a minimum; and when the velocity is a maximum, there is a tendency to scoop out a hole between each. (Fig. 9.) Important cases of this kind may be observed in many rivers, of which the Clyde and Tay are well-known instances; in each case there is a considerable sand-bank thrown across the entrance to the narrow channel at the head of the estuary. This bank, forming an obstacle to the flood tide, gave rise to the standing-wave motion of the water and the deposition of a number of sand-banks, at remarkably regular distances apart. The removal of these banks, by dredging, so as to permit the easy transmission of the momentum on the flood, and the free motion of the ebbing waters, has been one of the principal improvements in these rivers.

When water is running, under the action of gravity, but the motion is partly forced, and the material of the bottom is easily moved, the friction upon it seems to give rise to the formation of standing waves, frequently visible on the surface, by which the sand, or gravel is formed into a number of ripples, which are constantly changing their position. (Fig. 10.)

It now remains to apply the circumstances affecting the deposition of material by water, in explanation of the obstructions existing in the bed and at the entrance of tidal rivers; and, first, as to the effects produced by river water in its own channel.

The effect produced by the action of river water varies with the quantity and quality of the detritus it has to act upon, (some of the circumstances affecting which have been considered),—with the quantity of water in action, which will depend upon the extent of surface drained, and the quantity of rain which falls in the locality,—and with the course, size, and inclination of the channel. In examining the condition of any river, all these circumstances require to be carefully taken into consideration.

The detritus is chiefly carried down rivers during floods: it is on those occasions, that it is worn away from the surface of the adjoining lands, &c., and the increased quantity of water in the river is then best able to move it onwards. It will generally be found, that the size of the detritus is less, as the distance from the source increases, owing to the diminished inclination of the stream, and the consequently decreased velocity of the water; this, however, is modified by the additional quantity of water which is constantly supplied from branches, rivulets, &c.

What then becomes of detritus which has been brought to a point, from which the velocity of the water is not sufficient to remove it? It may be of a material reducible by the constant action of the water, and thus be removed piecemeal; or it may be of a harder nature, in which case it forms an obstruction to the course of the river, and may propagate a number of standing waves, which continually create below it in the bed of the river, a hole into which it at last topples over. This result is sometimes seen, when weirs, or piers of bridges obstruct the course of a river. If it cannot be thus removed, it may form a permanent obstacle in the river, and either divert it from its former course, or raise the bed of the river, as is the case with the River Po, the bed of which is above the level of the adjoining lands, its banks having been raised artificially by the material deposited, from time to time, in its bed, for the purpose of confining it to one course and permitting the cultivation of the rest of the valley.

Curves in a river give increased velocity to the stream on the concave side, which is lost when the river enters a straight reach, causing thereby a deposit of detritus; such deposit forms a natural weir which again gives rise to a succession of deeps and shoals, if other causes do not counteract the effect.

Shoals and deeps in the course of a river are constantly to be found arising from artificial obstructions. Thus the piers of a bridge which contract the water-way cause a head of water, which, checking the velocity of the current above, give rise to a deposition of detritus, whilst the water rushing impetuously between the piers of the

bridge scoops out a deep, and at a short distance below, a shoal is formed, caused by the first standing wave, with a succession of deeps and shoals below, gradually diminishing in extent. (Fig. 11.) In the same manner, a weir catches the detritus above it, and the water passing down with great velocity scoops out a hollow, with a corresponding series of shoals and deeps below.

In considering the action of the river when it discharges itself into a large body of water, it is proposed to examine the most simple case first, and then to proceed to the more complicated.

The most simple case seems to be, when there is no rise and fall of tide; for instance, rivers discharging into lakes. Cases of this kind are frequent in the Mediterranean: for example, the Nile, the Po, &c., in all of which deltas are formed at the mouths. Here there can be no material carried into the river from the sea, or lake; materials may, however, be deposited at the entrance, either by the wind-waves, or by the action of currents. Circumstances that would effect this, are pointed out by Captain Beechey, as existing on the east coast of Ireland, at Courtown, near Wexford, where there is no rise of tide, but a considerable current at a short distance from the land. Courtown is well open to the sea, and consequently, to the violent action of its wind-waves.

Supposing the river to discharge itself into an arm of the sea, (the plan and section being somewhat similar to Figs. 12 and 13,) the material brought down the river would evidently be deposited at the upper part of the arm of the sea, the coarse materials being deposited first, and the finer materials further down, giving a section as shown in Fig. 14. By degrees, the velocity of the water would become insufficient to carry the material over the edge of the deposit, and it would then be heaped up in the direct line of the current, causing a bar. The form of a bar, originating simply under such circumstances, and otherwise uninfluenced, would be very similar to a horse-shoe. (Fig. 15.) The greatest velocity of the water being in the line of the stream, it would be longest maintained, and the detritus would be principally carried forward in that line; whence it follows, that the deposit would be greatest and be heaped up to the highest level, in the line of the stream. This action gives rise to the formation of the delta, (Fig. 16,) the stream subsequently making its way right and left of the deposited material. The stream, thus divided, causes the formation of other similar deposits, which eventually give rise to further subdivisions, (Fig. 17,) thus forming a number of mouths, as in the Nile and other rivers.

In a delta so formed, it is clear, that the largest quantity of the detritus, borne along the diverging channels, would be carried along

the concave sides of the new courses, and at the first subdivision, the débris would be conveyed towards the centre of the delta, in consequence of which, the channel branching towards the centre would be more rapidly filled up, and the courses, at the outside of the delta, would remain of the greatest magnitude and become the main channels.

If the course of the stream, before it reached the delta, were curved instead of straight, the velocity of the stream on the concave side, carrying down a larger quantity of material, would fill up the channel diverging on that side, and there would be only one main channel, curving in the same direction as the stream above: this curved channel would, apparently, continue until there was some obstacle to its course. Such an obstacle would be presented by the sides of the valley which the river is gradually filling up: the course, thus diverted, would proceed in a curve in the opposite direction, and the same causes being in operation and the channel being self-forming, it seems probable, that the new curve would be of similar radius to the former one. Again: if the valley is pretty regular, the length of these curves would be very nearly the same. Mr. Brooks, in his work on the improvement of rivers,* mentions, that the windings of the Orinoco are extremely regular, the natives being in the habit of estimating distances by them.

When a bar, or delta is formed, the velocity of the water being checked, reacts, and, diminishing the velocity of the water above, causes a deposit in the bed of the river, so that as the river extends seaward, its bed is gradually raised and its inclination diminished. A greater depth thus becomes necessary, to give the requisite velocity for the conveyance of the detritus; and this is accomplished by constant deposition over the valley, until the river is confined within the proper limits of width and depth.

The effect of standing waves overcomes, in a great measure, the difficulty of insufficient inclination for the transport of the material. In this action a very rapid motion and a comparatively quiescent state take place alternately: the rapid motion moves forward detritus of greater dimension than the average velocity of the stream could have effected, supposing the motion to have been purely free, and the detritus is thus moved forward from one position to another, being always taken from the back of the standing bar, or ripple, and tipped over the summit; by degrees, it becomes uncovered, and is again moved onwards a step. This action may frequently be observed in running water.

* *Vide* "Treatise on the Improvement of the Navigation of Rivers, &c." By W. A. Brooks. London, 1841.

The effect of débris from the coast, whether driven across the entrance of the river by wind-waves, or deposited by an along-shore current in the bay, or arm of the sea, on which the deposit from the river is encroaching, will simply be to expedite the encroachment.

When a river discharges into a bay, or an arm of the sea, in which the water rises and falls, without much perceptible current, (which may easily be the case, if the arm is deep and not in the direct line of the tidal wave), there will be a check to the stream and a consequent deposit higher up the river, at the time of high water, than at other periods of the tide. (Figs. 18 and 19). Over the bar, thus formed, the water will fall with increased velocity, as the tide recedes, and it will form the first of a series of standing waves, and consecutive deeps and shallows, the last, or outer bar being below the level of low water. When this bar rises up, so as to form a barrier to the flux and reflux of the tidal water, the case is changed, and the effects resulting from the operation will be treated of separately.

The next subject to be considered is the action of the sea without the bar, or entrance to the river and the circumstances which affect it.

When a river, or estuary, lies near the outer limit of the submarine delta formed in the English Channel, &c., during the process of destruction of the tidal wave, there will, probably, be deep water at its entrance; but if it lies where the force of the tidal wave is destroyed, surrounded by the numerous shoals and sand-banks heaped up by it, a necessarily limited depth of water at its entrance is the consequence. Rivers and estuaries, near the Land's End, fall within the former category: those near the Thames and Morecambe Bay within the latter. When a portion of the great tidal wave sets directly up a river, or estuary, as in the case of the Bristol Channel and the Severn, the River of St. Michaels, &c., the momentum of the water is expended in raising a column of water to a great height; and in the upper part of such rivers, there are, generally, considerable sand-banks deposited.

A few observations here, on the motion of water in rivers and estuaries, when the tidal wave sets directly up them, will not be out of place.

From whatever source the ebb water is derived, it will have a fixed inclination of surface at low water, and will be moving with a velocity resulting from that inclination and the depth of the water in the channel. When the tidal wave reaches the entrance, there will be a tendency to motion inwards, which will diminish the velocity of the stream outwards; this process will go on, until the

momentum of the effluent stream is destroyed, and then the water will begin to flow in. Thus, if the moments of the two forces, at any point, are equal, there will be all the appearance of a purely oscillatory wave. From this would seem to arise the oscillating character of the great tidal wave, at the entrance of the English, Irish, and Bristol Channels, (which are merely huge estuaries,) and for a certain distance up them. This character led to the suggestion in a former Paper,* that the tidal wave was an oscillatory wave, and not a wave of translation, as stated by Mr. Russell. It appears probable that he is quite correct in his opinion, of the tidal wave being a pure wave of translation, and that its oscillatory character, in the channels above named, is due to the water being heaped up in these channels, its momentum in returning equalling, at certain points, that of the approaching flood-tidal wave. The oscillating character being maintained, so long as the channel continues pretty regular, whilst outside of the entrance, the momentum of the ebb being diffused and becoming shortly imperceptible, the tidal wave remains purely translative. Again; as the momentum of the ebb lessens in intensity, higher up the channel, the wave becomes more purely a wave of translation.

When the back water is derived from the former tidal waves alone, its momentum must, from the friction on the bottom, be less than the momentum of the flood wave, giving rise to a permanent extra quantity of water being heaped up in the channel, until an equilibrium is established throughout. This will explain some of the phenomena of the motion of the water, during the tides in the Irish Sea, an account of which was communicated, last session, to the Royal Society, by Captain Beechey, who discovered, that it was slack water throughout the Irish Channel, when it was high and low water in Morecambe Bay. (Fig. 22).

It seems very probable, that an analogous process occurs, during the destruction of wind-waves, where the wind is blowing directly on shore, and that to this they owe their oscillatory character, at a short distance from the beach. It is a fact, that the water is raised considerably, towards the shore, during a direct on-shore gale. It is probable also, that the character of the waves generated by the wind acting constantly in one direction, is translative, whereas at a short distance from the shore before they break, they are evidently oscillatory. Should this explanation be considered satisfactory, it will afford a clue to some most interesting peculiarities in the action of the breakers, on the shingle of the coast, &c.

The entrance of a river may be more, or less at right angles to a

* *Vide* Minutes of Proceedings Inst. C. E., vol. vii., p. 327 *et seq.*

coast, along which the great tidal wave sweeps, and upon the exact position of such an entrance, will greatly depend the presence, or absence of a bar. Thus if the entrance lies embayed, as at A (Fig. 20), the bar will probably be greater, than when the river debouches at B, as the current of the great tidal wave has, in the latter case, a tendency to maintain deep water. Were there no river at A, the effect of the tide, sweeping along the adjoining coast, would be the deposition of a quantity of material, there being merely a rise and fall of the water, without any very perceptible current in the bay. The extent to which this deposit takes place, appears to be limited by the depth of water maintained by the current between the projecting headlands, the depth of the bay, and the angle at which the sand, or other material deposited will lie. The sand may thus form a bar to a river, or it may, as at Yarmouth, produce an outer shoal, forming a protection to the roadstead outside of the river.

A sea-formed bar may exist, with very deep water, in the estuary within and for a considerable distance up it, whilst the formation of the bar of the river and the encroachment upon the upper part of the estuary is proceeding quite independently, and is, perhaps, very little affected by it. (Fig. 21). There is such a bar across the estuary at Salcombe.

In the case of many rivers, the wind-waves heap up the gravel, &c., towards their entrance, tending to, and often, actually blockading them: a subject which has been considered in a Paper presented to the Institution during the last session.*

In further considering the case of a river, or estuary, when the tidal wave sets at right angles to it, or when there is merely a rise and fall of the water, it is necessary to examine carefully the action at the entrance. In this case, the whole of the effects of the flood are dependent upon the rise of the water. As the water rises above the level of that adjoining, the equilibrium is destroyed, and there is an immediate tendency of the water to flow in. Now what circumstances regulate the quantity of water that flows in? The section for the entrance and a certain rise of tide, being, of course, always ascertainable.

If the water passing the entrance were allowed freely to escape, as for example, over a fall, it is clear, that even then, the quantity of water that passed, during the given tidal period, would be limited. Now in the cases under consideration, the water within is, at any rate, as high as that without, at low water;—still more, therefore, must the quantity of water flowing in during the tide, be limited.

* *Vide* Minutes of Proceedings Inst. C. E., vol. vii., page 327 *et seq.*

What then are the circumstances under which the quantity of water flowing in will be the greatest? It must depend upon the freedom with which the momentum which is generated by the difference of level, is transmitted to the water within the entrance.

The velocity of transmission of momentum through water is chiefly dependent upon the depth. When the channel is long and regular as to width, and of sufficient depth, a pure wave of translation is generated at the entrance; the greater the depth of the channel, the larger will be the quantity entering, because the more rapidly will the momentum be transmitted, and the lower the resulting level of the water within.

Mr. Russell, in his experiments on waves, found, that the wave of translation, on entering a large area, was laterally diffused, the height of the wave gradually diminishing on each side, but continuing largest in the direction in which it was generated; thus showing, that there is a limit to the effect of suddenly-increased width. A consideration of this will explain the cause of the eddies which are found in such cases. (Fig. 23).

A wide expanse within the entrance must, however, draw into it an excessive quantity of water.

The circumstances which lessen the quantity of water flowing in, are:—1st. A confined space within;—2ndly. A shallow channel; 3rdly. Effluent water.

The effect of a confined space within is evident, it is soon filled; but the *modus operandi* is important. The momentum generated at the entrance is rapidly destroyed on the shore, and then the tendency of the water is to fall back toward the entrance: this reaction checks the water flowing in and keeps it at a higher level, thus diminishing the velocity and consequent influx of water.

When the channel is shallow, the momentum generated at the entrance cannot be transmitted; it is, consequently, expended by the friction on the bottom, and in raising up a column of water forming a standing wave. The friction causes the removal of the material from the bed of the channel, which, as the velocity diminishes, is deposited, and forms banks. The standing wave acts in a similar manner to the confined space; the momentum is destroyed in forming it, and the reaction checks the flow and diminishes the head at the bar. This action principally goes on near low water; for when the tide rises, the depth of water within permits the freer transmission of the momentum.

The effect of effluent water has, to some extent, been considered, in treating of the direct action of the tidal wave. Where there is a considerable quantity of back water from a river, there may be a

flow of water, out of the channel, during the whole of the tide, the tidal wave, whether generated by the difference of level at the entrance, or part of the primitive wave, merely raising the level of the effluent stream and lessening its velocity. In this manner, waves are found passing up many rivers in America, their existence being apparent, by the check given to the velocity of the water flowing down, and by the simultaneous rise of its level.

It may be deduced from this and from the known small resistance which water presents to the transmission of momentum through it, that a somewhat similar wave form is transmitted up a river, whether there is a corresponding motion of the water in the same direction, or merely a retardation of the motion in the opposite direction; the front of the wave being more abrupt, as the resistance to its progress increases.

There does not appear to have been any experiments made, for the purpose of ascertaining, whether the velocity of a wave is diminished by the motion of the water in which it is propagated, being opposed to it; but from the well-known ease with which waves cross each other without alteration, there would seem to be but little diminution from this cause.

Where the momentum of the flood is in excess, the bore, as in the Amazon and other large rivers, seems to be the result of the opposition of the flood and the ebb, but the insufficient depth of water for the free transmission of the wave is, probably, the principal cause. The bore in the Severn, &c., results from the want of water for the wave to be propagated in, the friction on the bottom retards the passage of the water, and the momentum of the water, in the after part of the wave, acting upon the smaller quantity which is retarded in front, pushes it on, causing a continuous breaker.

It has been observed, that bars are sometimes formed from the material carried down by the river, and deposited where the velocity of the stream is diminished, as it reaches the deeper water; sometimes, by the wind waves driving the shingle across the mouth; sometimes, by the sand carried along the coast by the along-shore tidal currents which, escaping into the bay into which the river discharges, settles there, forming the bar; and sometimes, by a combination of all these.

In considering the subject of bars, it is, evidently, most desirable, that they should be removed by the ebb tide, so that the materials may be carried into the deep water of the sea and not into the river. The manner in which this object is best effected by the simple action of the water, unassisted by art, is by its flowing over the bar on the ebb, in the greatest quantity and with the maximum velocity, near

low water. This velocity arises from the free motion of the water over the bar, caused by the difference of level within and without it, in which case the materials are carried forward, (Fig. 24): not from the forced motion of the water which occurs, when the momentum of the water flowing down the river, forces the water out over the bar. (Fig. 25.) When the motion of the water in approaching a bar is forced, its tendency is to carry the material forward and to heap it up, thus making the fan-shaped bar the arc of a greater circle, over which the water passes with a less head, and consequently, diminished effect in removing the material outwards. (Fig. 26.) Free motion of the water, over a bar, can only exist, when the bar is, literally, the barrier to the egress of the ebb waters. A narrow part of the river within the bar will, for instance, be frequently found to limit the efflux of the water; in such cases, the water rushes through the narrow with great velocity, scooping out a deep and forming a standing wave and bar. (Figs. 25 and 26.) A sharp turn near the entrance often acts in the same manner, the head of water being formed at it, (Fig. 27;) this is frequently the case with bottle-necked estuaries.

It being desirable to have the largest quantity of water flowing over the bar on the ebb, with the maximum velocity towards low water, the motion of the water being free, what are the circumstances which most conduce to this end?

A deep river with a large quantity of land water and the inclination of the surface slight, is, perhaps, the most effective.

When, however, the principal part of the back water is the tidal water, the deeper the channel can be maintained and the greater the distance the water can be made to flow up it, the more the effect of the ebb will resemble the former most effective case.

When the water, which has entered on the flood, is contained in a large reservoir near a comparatively narrow entrance, the entrance will, necessarily, form the barrier to the ebb of the water, a constant head being maintained at it, the greater in proportion as the entrance is narrower.

On the flood, the less the velocity of the water over the bar and the more smoothly the momentum generated by the head of water at it can be communicated to that within, the better, as the material composing the bar is less liable to be carried inwards.

Whenever the bar is so high, or the entrance so narrow, as to cause a considerable head of water, the production of standing-wave action is the necessary consequence, the effect being to scoop out a deep within the bar and to form, at no great distance, a sand, or gravel-bank.

It is, therefore, desirable to have as much water as possible returning at low water, so that the first part of the flood may be employed in checking the efflux, and that the actual influx may occur near high water, when the momentum would be more easily transmitted up the river, and with less power to move the sand, &c., in consequence of the diminished velocity of the water.

A long deep channel is, consequently, decidedly the best for the maintenance of a deep entrance:—1st. That the flood water, by having a long distance to flow up, may return in the greatest quantity near low water, when it would be most effective in removing the bar outwards. 2ndly. That so returning at low water, it may check the rapid entrance of water on the early flood, and so prevent the removal of sand, &c., from the bar into the river.

Such an extended space as Jarrow Slake, on the Tyne, not only checks the flow of the water up the river, but returns the water it contains, at nearly high water, when it cannot have any effect in removing the bar.

The bar will not always be found a barrier to the flood tide, the narrowness of the entrance, &c., being frequently the actual cause of the increased head and consequent velocity inwards.

There is one advantage arising, occasionally, from the presence of bars, which it is not fair to overlook, among the many disadvantages; that is, the very deep channel which is, in very many cases, to be found for a short distance up the river, immediately within the entrance. These deep channels owe their existence to the standing-wave action of the water, during its free motion from the head at the bar, or narrow entrance, as the case may be; and they are highly valued, as affording berths for ships of considerable draught of water. Now the effect of improving the entrance so as to give a greater depth of water there, would frequently be to diminish the depth of this inner channel, which would be considered, in many instances, more injurious to the harbour, in a commercial point of view, than an unaltered condition of the bar. Within some rivers, a depth of 30 feet at low water may be found, over the bar, where there is not 16 feet of water over the bar, at spring tides; in such cases, the bar may, evidently, be considerably reduced, without injuriously affecting the depth of the inner channel, which would be highly advantageous, especially when the consequent general improvement of the river further up is taken into account.

Having examined the circumstances which regulate the quantity of water flowing in and out of a river, or estuary, and its effect on the bar, the action of the water upon the materials forming the bed of the channel is the next subject that calls for consideration.

There is a striking and most important difference between the motion of the water on the flood, and on the ebb:—on the flood, the motion of the water is forced, a certain quantity of momentum being transmitted from particle to particle;—on the ebb, the motion of the water is free, arising from its tendency to assume a level surface. The effects of these motions have been treated of in a former part of this Paper.

When the character of the wave is oscillating at the entrance, the back action draws out the material at the bottom. This action lessens as the wave loses its oscillatory character, and at a certain point, the wave becoming entirely translative, the material is carried forward and forms an incline, up which the wave expends its force. The large sand-banks formed in the Severn, the Clyde, the Tay, the Thames, &c., and those at Morecambe Bay and in the North Sea, opposite the Thames, are the result of this action. When, as in these cases, the momentum of the flood, in passing over the banks, is considerable, they are very flat, gradually becoming raised towards the upper part, as the momentum is diminished by the friction upon them. The banks thus formed will be found to exhibit, more or less, the character of those which result from the action of standing waves. (Fig. 9.) The momentum may be entirely expended upon these banks, or there may exist comparatively deep water within them, the estuary being but partially filled up. (Fig. 28.)

It is quite possible for the sand to be thrown up, in this manner, by the flood tide, so as to shut in the water entirely in the upper part, forming, as it were, a lake.

When a large estuary suddenly narrows considerably, a sand-bank is frequently formed across the narrow part, through which the river on ebbing is obliged to cut a channel; for example, the entrance to the Clyde, at Port-Glasgow and the Tay, at Newburgh.

The direction of the wave generated at the bar of a river, or estuary, will be in a line at right angles to the bar; consequently, in that line there is the greatest probability of deposition of material. This gives rise to the form and situation of the sand-banks generally found within a bottle-necked bar estuary. (Fig. 29.) The bank A is thus raised to the greatest height. For a considerable part of the early flood, it dams the water back and forces it to go in the deep-channel course, the generating head of water being within the entrance; the momentum is thus transmitted up the deep channel, from which the water always tends to fly off at a tangent, and does so, as soon as it can, depositing the material it carries, and forming a sand-bank as at B, and again, for similar reasons, at C. When the water rises, so that it passes over the bank A, the head of water is no

longer within, but outside, of the mouth; the velocity is then greatly increased at the narrow entrance, and quantities of coarse material removed from it and the bar, are deposited at the first bank A. A standing wave being formed at A, the water rushes from it directly up the estuary, carrying forward the sand from B, and depositing it in one large bank in about the line D E, at which part the ebb water generally forms several channels, shifting, shallow, and insignificant.

A different account was given in a former Paper* of the formation of the bank A, (called the inner tongue,) in the case of the River Teign. From careful observation since that Paper was presented to the Institution, it is believed, that the above is the correct explanation of the process of deposition.

The position of the sand-bank at D E varies in different rivers: the ebb may be able to maintain a deep channel, meandering round several minor banks formed as above, but there seems to be, in all rivers of the description under consideration, a sand-bank thus formed, stretching across the entire estuary. When the flood tide forms these sand-banks in the manner described, a false channel will be formed at each of them, giving the estuary, at low water, the form shown in Fig. 30, A, B, C, D, being false channels formed by the flood tide. On the ebb, the velocity of the water is greatest, when the channel is deepest, and generally, the effects are similar to those produced by the water in rivers proper.

In determining the measures which are necessary to remedy the injurious deposition of materials in rivers, it should always be borne in mind, that the two great primary sources whence the gravel and sand are derived, are the detritus brought down the rivers during floods, and the débris from the coast carried into them by the flood tide. These sources of mischief should, when it is possible, be the first attacked.

Is it then possible to stop the detritus above the tidal influence, or to lessen the quantity which is being constantly carried down rivers? It is, certainly, possible, to lessen the quantity considerably; for instance, by forming a dam, or weir across one of the narrow rocky gorges which occur in most rivers, a large receptacle might be formed above, for the detritus of many years, but to this there would, generally, be the great objection of its rendering useless fine meadow land which had been reclaimed. Again; by judicious groyning, the encroachment of the river on the sides of the valley might very frequently be diminished, if not entirely stopped, and this would not be subject to the same objections as the former process.

* *Vide* Minutes of Proceedings Inst. C.E., vol. vii., p. 327, *et seq.*

In rivers there are generally to be found extensive areas of shingly stones, through which the river is ever changing its channel, first depositing its detritus in one position, and then being diverted, by its own deposit, into another course; such areas are of the greatest importance, as they form places of deposit. Now these areas are always looked upon as reclaimable, by the owners of the land adjoining, and steps are constantly taken to confine the river to one channel through them, so as to effect the conversion of the remainder into land. This should, certainly, not be permitted; for as below the tidal range, it is desirable to confine the channel for the purpose of scouring and removing deposit, so above that range, the more the river is left unconfined the better, so as to encourage deposit.

Again; by groyning the coast, much may be done towards stopping the progress of the shingle which, by its accumulation against the cliffs, prevents the further encroachment of the sea upon them. And by carrying out piers into the deeper water, the formation of a bar at the entrance may, in many cases, be prevented, and the effect of the ebb, on one already existing, will be more concentrated and effective, especially if the piers are so lengthened, that a cross current could remove the materials carried out by the river.

In designing piers for concentrating the effect of the ebb on a bar, great care is required in deciding upon the width between them. If they are too narrow, the water penned back above, rushes between them with immense velocity, scooping out a deep channel in its passage, and meeting the bar at the entrance, expends its violence in carrying it further out and heaping it up. This disadvantage will be greatly increased, when the tidal water is contained in a large receptacle near the entrance. A similar action will also take place, during the flood, thus constantly tending to undermine the piers, and to form a bar both within and without the entrance. (Figs. 31 and 32.) If the width between the piers is too great, there will be a tendency to deposition between them, with a consequent formation of banks, through which a channel must be maintained by the ebb, which channel must be, to a great extent, uncertain and moveable. The desideratum seems to be a width nearly similar to the course of the river to be maintained above, the depth between them being maintained also similar, so that the wave, propagated at the entrance, may be as pure a wave of translation as possible.

The effect produced upon the bar, by curving the piers, is to cause the highest part of the bar to be nearest the concave pier, instead of immediately in front of the entrance, as when the course out is straight. (Fig. 33.) The advantage of a curved pier seems to be, the insuring a deep channel by the side of the pier, and so removing

the objection to the width between the piers being too great. A small channel is apt to form at A; this is chiefly kept open by the flood tide which, towards high water, sets across the main channel with great velocity.

When it is desired to improve a tidal river, every obstacle which checks the flow of the tide up the river should, first, be removed, and such places as Jarrow Slake, on the Tyne, should be enclosed. A small extent of beaching ground, within the entrance, is generally necessary, that the wind-waves entering, may expend their force upon it, and not proceed up the river to disturb the shipping; but when the entrance is artificial, this object may be sometimes better attained, by land-locking it.

In arranging the lines for the channel of the river intended to be maintained, advantage may, occasionally, be taken of the different action of the water, when forced during the flood and running freely on the ebb. In the former case, the velocity being greatest over the shallows and least over the deep, and in the latter, the reverse.

All curves in the course of the channel diminish the velocity of the flood tide, some of its momentum being constantly expended in changing the direction; the process seems to be, that the water is heaped up against the concave side, which accumulation generates a wave, more, or less, across the channel. (Figs. 34 and 35.) Curves are, therefore, to be avoided, and when necessary, should be of as large a radius as possible; they should, when reversed, be passed gently from one to the other, without any intermediate straight line, which is objectionable for reasons mentioned before. Where it is necessary to join a curve into a straight line, the curve should become, gradually, of larger radius downwards.

It is not pretended, that this Paper thoroughly explains the action of the flood and ebb tide, in all rivers and estuaries; each presents peculiarities and many anomalies, some of which will, probably, be raised as objections to the whole theory. The observations are presented to the Institution as an approximation to the solution of the interesting subject treated of, and with the hope, that they may lead to discussion and to a further collection of facts, upon which alone any sound theory can be founded.

The Paper is illustrated by a series of diagrams, from which Plate 9 is compiled.

Mr. Scott Russell was glad to receive a confirmation of the correctness of his experiments, when applied to the theory of tidal rivers and running streams. He agreed with the Author, that the phenomena attendant upon the standing wave had much to do with

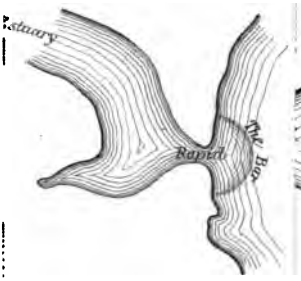
the formation of bars, as in the cases of the Clyde, the Tyne, &c.; but he thought, that a too limited idea had been taken of the action of water. It was impossible to obtain one simple action; there were always several others coincident with and consequent upon it; for instance, continual friction was going on between the particles of water in motion, producing a kind of pendulous action throughout. By erecting groynes, or scouring the channels of rivers, certain desired effects might be obtained; but frequently, these operations were also attended with unforeseen and embarrassing results, such as obstructions in the course of the river, or the formation of bars. Running water, meeting with a shoal in the bed of the stream, increased its velocity, in order to pass the same volume through a less space, but the power was afterwards expended in excavating a deep, immediately beyond the obstruction, and heaping up the material removed, to a lower part of the river, and the continued repetition of these phenomena led, eventually, to the formation of either outer bars, or inner bars, according to the peculiar local circumstances. When a lateral strangulation occurred in a channel, the water from one side was reflected towards the other, scooping out a hollow immediately below, after which it diverged to either side of the enlarged channel, leaving a deposit in the centre of the two currents. This reflection of the water was the main cause of the formation of deltoids. In the River Dee he had uniformly found these effects below every strangulation, the water suddenly diminishing from 9 feet, to as many inches.

In all operations for the improvement of rivers, care should be taken not to attempt to cure an evil by a purely local remedy, for it would rarely be effectual. Every effort should be made to give one symmetrical contour, to form gradual curves, and to obtain an uniform depth, avoiding all causes of sudden check to the free passage of the water.

After the Meeting, Mr. F. A. Carrington exhibited in the Library a model, in relief, of portions of the counties of Lancashire, Yorkshire, Cheshire, Nottinghamshire, and Derbyshire, extending from Manchester, on the west, to Lincoln and the Humber, on the east; and from Leeds and Bradford on the north, to Chetsworth Park on the south. These models showed, at one view, the whole physical geography of the district, and were admirably calculated for projecting works of both civil and military engineering; and if they were more frequently made use of, when designing works for the sanitary improvements of towns, the progress would be more certain, and less costly.

Fig. 27.

PLAN.



ICTION.

Fig. 31

PLAN.

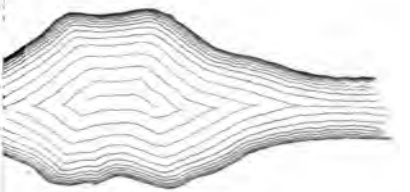


Fig. 32.

GITUDINAL SECTION.

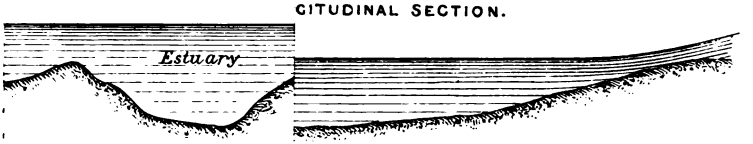


Fig. 33.

PLAN.

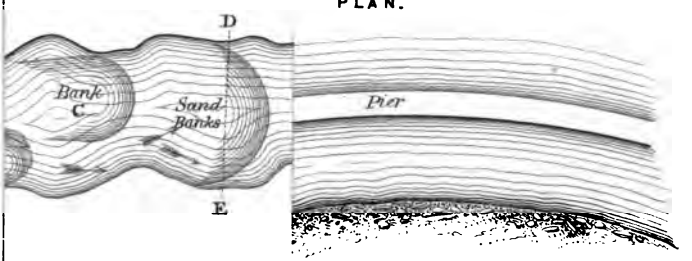


Fig. 34.

PLAN.

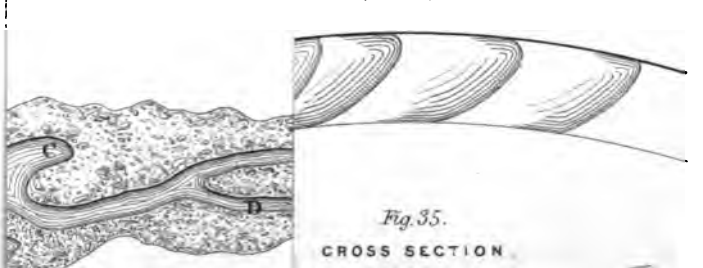
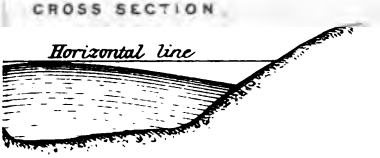


Fig. 35.

CROSS SECTION.



KELL BROS LITH 86 CASTLE ST HOLBORN.

July 10, 1849.

JOSHUA FIELD, President, in the Chair.

SPECIAL GENERAL MEETING.

THIS Meeting was convened for the purpose of considering and deciding upon certain proposed alterations in the Bye-laws, Sections III., IV.. V., VIII., X., and XI., as announced in the summons to the Members.

The alterations were generally discussed, and were passed unanimously; and they were ordered to stand as part of the Bye-laws and Regulations of the Institution.

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